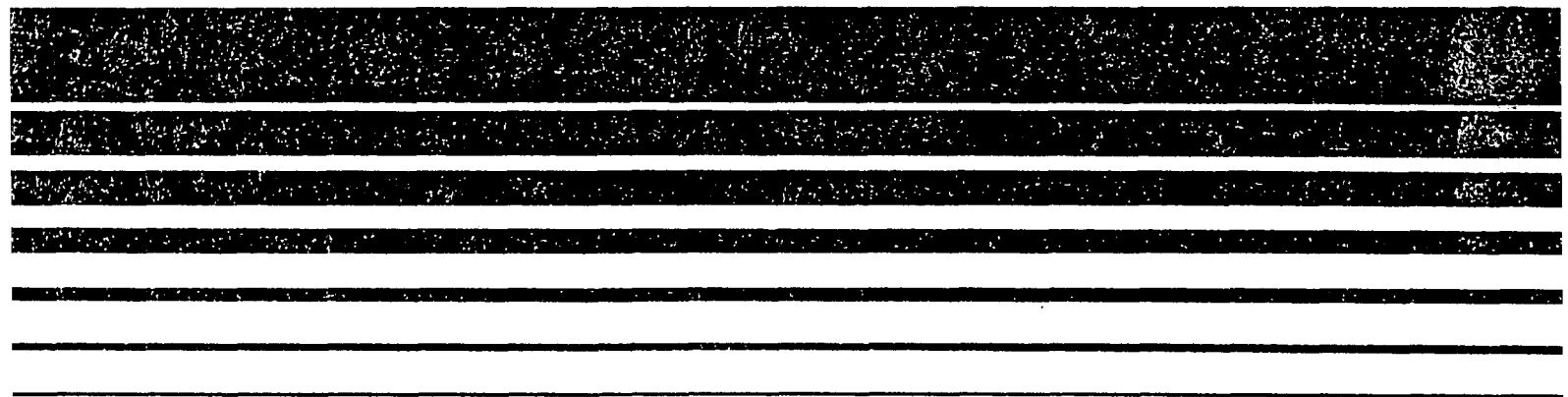


Air



# NESHAP - Glass Manufacturing Arsenic

Emission Test Report  
Indiana Glass Company  
Dunkirk, Indiana



SUMMARY TEST REPORT

STANDARDIZATION AND VALIDATION OF  
METHODOLOGY TO MEASURE INORGANIC  
ARSENIC EMISSIONS FROM  
STATIONARY SOURCES  
Indiana Glass Company  
Dunkirk, Indiana

by

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Contract No. 68-02-3767  
Work Assignment No. 66  
Change No. 1  
PN 3583-6

and

Contract No. 68-02-3849  
Work Assignment No. 11  
PN 3615-11

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October 1984

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## ACKNOWLEDGMENT

This test program was conducted for the Emission Standards and Engineering Division of the EPA Office of Air Quality Planning and Standards. The program was part of a larger study directed by EPA's Source Branch of the Environmental Monitoring Systems Laboratory, Quality Assurance Division, to evaluate proposed EPA Method 108. Mr. Thomas E. Ward was the EMSL Task Manager.

Mr. Daniel Bivins, EPA-EMB Task Manager, provided overall project coordination and guidance and observed the test program. Mr. Ronald Myers, EPA lead engineer, Industrial Studies Branch, provided project coordination relative to process operation and overall project scope. Mr. Larry Keller, representing Radian Corporation (an EPA contractor) monitored process operation throughout the test period. Mr. Charles Bruffey was the PEI Project Manager. Principal authors were Messrs. Charles Bruffey and Thomas Wagner.



SECTION 1  
INTRODUCTION

Arsenic is listed as a hazardous air pollutant under Section 112 of the Clean Air Act (National Emission Standards for Hazardous Air Pollutants). To protect public health from unreasonable risks associated with exposure to airborne arsenic, the U.S. Environmental Protection Agency (EPA) has developed standards to decrease inorganic arsenic emissions from the following source categories: high-arsenic primary copper smelters, low-arsenic primary copper smelters, and glass manufacturing plants.

To support the standards review process and provide additional arsenic emissions data from glass manufacturing facilities, PEI Associates, Inc., under contract to Research Triangle Institute and directed by the Source Branch of the EMSL Quality Assurance Division and the Emission Standards and Engineering Division - Emission Measurement Branch, performed a series of atmospheric emission tests on a glass melting furnace at Indiana Glass Company in Dunkirk, Indiana. These tests were conducted from May 17 through 19, 1984, as part of a larger study designed to evaluate the sampling and analytical procedures for measuring inorganic arsenic from stationary sources. Proposed Method 108\* provides total arsenic results (particulate plus gaseous fraction).

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\* 40 CFR 61, Appendix B, Method 108, July 1983.

The primary objective of this test program was to determine the precision of proposed Method 108. Relative standard deviations (the standard deviation expressed as a percent of the mean value) of four-train (quad) sample runs were used to estimate method precision. A total of nine quad train runs representing 36 individual samples were conducted using Method 108 sampling and analytical procedures as described in the Quality Assurance Project Plan developed and submitted in January 1984 to the EPA Environmental Monitoring Systems Laboratory. These data are summarized in a report issued to EMSL-QAD.

In this specific portion of the test program, four quad-train tests were conducted using Method 108 procedures except that probe and filter temperatures were elevated to approximately 204°C and 288°C in order to evaluate the effects of increased sampling train temperature on arsenic distribution in the sampling train. During these runs, a single Method 108 sampling train (121°C) was run for reference purposes. Three Method 108 traverse tests were also conducted to provide additional data in support of the arsenic standards developed to date.

Section 2 summarizes and discusses the test results; Section 3 addresses quality assurance considerations specific to this project; Section 4 describes the sampling locations and test procedures; and Section 5 describes source operation. Appendix A presents sample calculations and computer printouts; Appendices B and C contain the field data sheets and laboratory analytical

results, respectively; Appendix D details the sampling and analytical procedures; Appendix E summarizes equipment calibration procedures and results; and Appendix F contains a process description and the furnace operating data for the test period.

## SECTION 2

### SUMMARY AND DISCUSSION OF TEST RESULTS

#### 2.1 SAMPLING AND ANALYTICAL PROTOCOL

A four-train (quad) sampling system was used to collect samples at the furnace exit stack. This system allows four trains to sample simultaneously at essentially a single point in the stack (see Section 4).

Because this sampling approach allows simultaneous sampling at essentially a single point, it reduces the effect of variations in the velocity and particulate profiles on the sampling results. It also permits a statistically significant number of samples to be taken in a short amount of time. Further, since two of the four trains are identical for every run, the within-train precision can be determined at the same time as the relationship of the different trains is being compared.

The Quad runs conducted were designed to evaluate the effect of arsenic collection at elevated sampling temperatures. Two of the trains were heated to approximately 204°C (400°F) and two trains were heated to approximately 288°C (550°F) for comparative purposes. Additionally, in three of the four quad tests conducted, backup filters were maintained at approximately 121°C (250°F) prior to the impinger section.

Figure 2-1 depicts the quad train configuration used for these tests. Individual train components were recovered and analyzed for arsenic separately to evaluate the distribution of arsenic in the sampling train. In each train, the contents of the first and second impingers were recovered, combined, and analyzed for arsenic and the third and fourth impingers were recovered, combined, and analyzed for arsenic. The probe rinse and front filter were recovered and analyzed according to procedures defined in Method 108. In Trains A and D, the back-half glassware of the front filter, the glass connector, and the front-half glassware of the backup filter were rinsed with 0.1 N NaOH and this rinse was analyzed for arsenic. The backup filter was analyzed separately in each case.

During these runs, a single Method 108 sampling system (designated RT) (121°C) was run for reference purposes. Three multipoint traverse tests utilizing a single Method 108 train were also conducted at the completion of the quad-train tests.

In each train, the probe and filter temperatures were set at a predetermined temperature and monitored using multiterminal digital indicators with thermocouple leads located in each probe and immediately behind the Method 5 filter frits.

## 2.2 TEST RESULTS--ELEVATED TEMPERATURE RUNS

Table 2-1 summarizes sampling conditions for the quad train, reference train, and traverse train (designated CD) test runs. Table 2-2 summarizes the arsenic analytical results by sample

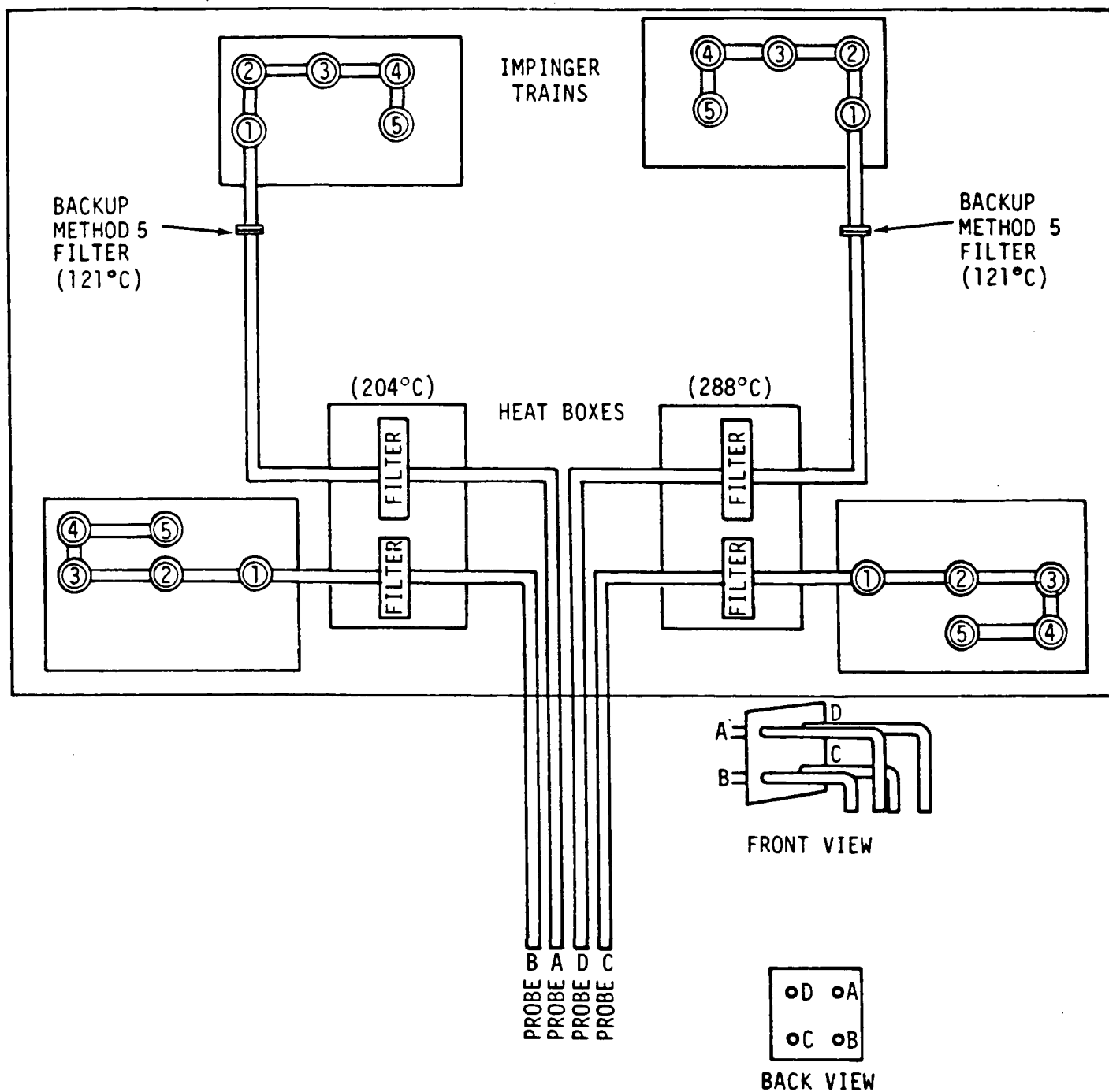


Figure 2-1. Quad train system for elevated temperature tests.

TABLE 2-1. SUMMARY OF SAMPLE CONDITIONS

Run No.	Sampling type	Date (1984) and time (24-h)	Metered volume, dsm <sup>3</sup>	Isokinetic, %	Moisture, %	Sampling conditions		Filter temperature, °C	Backup filter temperature, °C
						Gas temperature, °C	Probe temperature, °C		
10A	Modified Method 108	5/17 11:45-12:55	1.07	101.0	8.4	298	208	204	91
10B			1.12	97.5	8.9	298	206	206	NA
10C			1.18	101.2	8.4	298	248	284	NA
10D			1.09	100.4	8.6	298	178	286	120
10-RT	Method 108	5/17 11:45-12:55	1.41	96.0	8.1	301	121	121	NA
11A	Modified Method 108	5/17 17:11-18:21	1.02	101.2	8.5	301	193	201	NA
11B			1.12	97.8	6.9	301	200	210	NA
11C			1.14	100.2	8.3	301	295	262	NA
11D			1.00	99.3	8.8	301	286	285	NA
11-RT	Method 108	5/17 17:11-18:21	1.33	98.7	8.4	311	121	124	NA
12A	Modified Method 108	5/18 10:59-12:09	1.23	107.1	8.6	286	205	208	118
12B			1.33	103.0	8.4	286	210	210	NA
12C			1.34	101.2	8.6	286	279	261	NA
12D			0.29	101.2	9.1	286	174	284	104
12-RT	Method 108	5/18 10:59-12:09	1.53	99.8	8.5	292	121	122	NA
13A	Modified Method 108	5/18 15:36-16:46	1.14	94.5	8.9	274	208	206	122
13B			1.28	98.2	8.7	274	209	209	NA
13C			1.30	101.4	8.6	274	281	239	NA
13D			1.13	100.0	9.7	274	279	263	121
13-RT	Method 108	5/18 15:36-16:46	1.37	100.6	9.0	301	121	122	NA
CD-1	Method 108	5/19 10:32-11:45	1.03	105.6	8.0	260	147	143	NA
CD-2	Method 108	5/19 13:05-14:18	1.06	102.1	8.3	255	188	124	NA
CD-3	Method 108	5/19 15:12-16:22	1.07	100.3	7.7	248	180	123	NA

TABLE 2-2. SUMMARY OF ARSENIC ANALYTICAL RESULTS  
QUAD AND REFERENCE TRAIN RUNS

Run No.	Sample volume, dNm <sup>3</sup>	Arsenic sample weights, mg								Concentration, mg/dsm <sup>3</sup>		
		Probe rinse	Front <sup>a</sup> filter	Total front half	Back-half <sup>b</sup>							
					Glass connector	Backup filter	Impingers 1 & 2	Impingers 3 & 4	Total back half	Front half	Back half	Total train
10A	1.07	0.323	8.50	8.82	0.05	0.05	0.05	0.05	0.05	8.24	-	8.24
10B	1.12	0.686	9.26	9.95	NA	NA	0.05	0.05	0.05	8.88	-	8.88
10C	1.18	0.483	9.81	10.29	NA	NA	0.05	0.05	0.05	8.72	-	8.72
10D	1.09	0.775	9.81	10.59	0.05	0.05	0.05	0.05	0.05	9.72	-	9.72
10-RT	1.41	1.09	11.17	12.26	NA	NA	0.05	NA	0.05	8.70	-	8.70
11A	1.02	0.792	7.57	8.36	NA	NA	0.05	0.05	0.05	8.20	-	8.20
11B	1.12	0.666	9.19	9.86	NA	NA	0.05	0.05	0.05	8.80	-	8.80
11C	1.14	0.618	8.98	9.60	NA	NA	0.05	0.05	0.05	8.42	-	8.42
11D <sup>c</sup>	1.00	0.468	1.75	2.22	NA	NA	2.38	0.21	2.59	2.72	2.59	4.81
11-RT	1.33	1.21	11.17	12.38	NA	NA	0.05	0.05	0.05	9.31	-	9.31
12A	1.23	0.280	10.48	10.76	0.05	0.05	0.05	0.05	0.05	8.75	-	8.75
12B	1.33	0.786	10.86	11.65	NA	NA	0.05	0.05	0.05	8.76	-	8.76
12C	1.34	0.490	10.96	11.45	NA	NA	0.05	0.05	0.05	8.54	-	8.54
12D <sup>d</sup>	0.292	0.627	2.05	2.68	0.05	0.05	0.05	0.05	0.05	9.18	-	9.18
12-RT	1.53	1.11	10.79	11.90	NA	NA	0.05	0.05	0.05	7.78	-	7.78
13A	1.14	0.926	9.26	10.19	0.05	0.05	0.05	0.05	0.05	8.94	-	8.94
13B	1.28	0.866	10.55	11.42	NA	NA	0.05	0.05	0.05	8.92	-	8.92
13C	1.30	0.845	10.35	11.20	NA	NA	0.05	0.05	0.05	8.62	-	8.62
13D	1.13	0.786	9.55	10.34	0.05	0.05	0.05	0.05	0.05	9.15	-	9.15
13-RT	1.37	1.31	11.50	12.81	NA	NA	0.10	NA	0.10	9.35	0.07	9.42

<sup>a</sup>The front filter data include the Parr bomb results, which constituted approximately 1 percent of the total arsenic on the filter.

<sup>b</sup>NaOH rinse and impinger solution blank values ranged from 0.0 to 0.05 mg, therefore, back half values less than 0.05 mg are not reported.

<sup>c</sup>Run 11D is considered void due to a ruptured filter frit and subsequent loss of sample (see Pages 2-8 and 2-12).

<sup>d</sup>Run 12D was terminated approximately 14 minutes into the test due to a ruptured filter frit support (see Page 2-12).



fraction, and Table 2-3 presents statistical data for the grouped quad runs.

Sample volumes were consistent and ranged between 1.00 and 1.34 dsm<sup>3</sup> for the quad runs conducted during the full test period. Quad Run 12D was terminated approximately 14 minutes into the test due to a broken filter frit; the sample volume for this run was 0.292 dsm<sup>3</sup>. Sample volumes for the reference train tests ranged between 1.33 and 1.53 dsm<sup>3</sup>. Isokinetic sampling rates ranged from 96.0 to 107.1 percent, which is within the acceptable range of 90 to 100 percent. The probe and filter temperatures represent average values determined from data recorded on the field data sheets. The desired temperature for paired Trains A and B was 204°C and for paired Trains C and D, 288°C. As shown, filter temperatures for Trains A and B ranged from 201°C to 210°C and the probe temperatures ranged between 193° and 210°C. In Trains C and D, the filter temperatures were more variable ranging between 239° and 286°C, and the probe temperatures ranging from 174° to 295°C. The backup filter temperatures in Runs 10A and 10D, 12A and 12D, and 13A and 13D ranged from 91° to 122°C. No backup filters were utilized for Quad Run 11. In each quad test, the reference train probe and filter temperature was maintained at approximately 121°C.

The moisture content of the stack gas was generally consistent in each run, and the average gas temperatures ranged from 274° to 310°C.

As shown in Table 2-2, arsenic sample weights are reported in milligrams (mg) for each sample fraction analyzed. The front

TABLE 2-3. STATISTICAL DATA FOR GROUPED RUNS

Quad Run No. <sup>a</sup>	Individual run value	Group mean $\bar{x}$ <sup>b</sup>	$\sigma$ , <sup>c</sup> mg/dsm <sup>3</sup>	RSD, <sup>d</sup> %
10A	8.24	8.89	0.617	6.9
10B	8.88			
10C	8.72			
10D	9.72			
11A	8.2	8.47	0.304	3.6
11B	8.80			
11C	8.42			
11D	4.81			
12A	8.75	8.68	0.124	1.4
12B	8.76			
12C	8.54			
12D	9.18			
13A	8.94	8.91	0.218	2.4
13B	8.92			
13C	8.62			
13D	9.15			
Overall means		8.74 <sup>e</sup>	0.367 <sup>f</sup>	4.20 <sup>g</sup>

<sup>a</sup>Sample Nos. 11D and 12D are considered invalid and are not included in the group data.

<sup>b</sup>Mean concentration.

<sup>c</sup>Within-run standard deviation with N-1 weighting for sample data.

<sup>d</sup>Within-run relative standard deviation is the standard deviation expressed as a percent of the mean concentration.

<sup>e</sup>Simple averages of tabulated data.

<sup>f</sup>Pooled standard deviation;  $\sqrt{\frac{\sum \sigma^2}{n}}$ .

<sup>g</sup> $\overline{RSD} = \sqrt{\frac{\sum \sigma^2}{n}} / \bar{x}$ .

filter weight includes results for both the NaOH extract and the Parr bomb (HF/HNO<sub>3</sub>) extract. The extract results constituted approximately 1 percent of the total arsenic on the filter.

Arsenic was found mainly in the front half (probe and filter) of each of the 16 individual trains with the exception of Run 11D. During this run, the filter frit support ruptured but sampling continued until completion of the run. Obviously, some arsenic was carried to the back half of the sampling train as evidenced by the reported weight (2.59 mg) in the back half. Run 11D is considered an invalid sample and is not included in any of the grouped averages or statistical calculations.

The total amount of arsenic found in the front half was 99 percent in each case, and at least 90 percent of this amount was found in the filter fraction. No significant amount of arsenic was present in any of the back-half components. The 0.05 mg limit reported in Table 2-2 was established after careful analysis of the sample "blank" data. These data are summarized in Section 3 of this report. In summary, 60 percent of the blank values for the NaOH rinse and H<sub>2</sub>O impinger solutions were at or below the analytical detection limit (0.002 to 0.005 mg); the remaining blank values ranged up to a maximum value of 0.05 mg. Values below 0.05 mg were considered insignificant because the back-half arsenic content constituted less than 0.5 percent of the total arsenic collected, the liquid fraction blank data were variable, and 8.4 mg was the minimum amount of arsenic collected in any one train run for at least 60 minutes. Note that in Run

12D, the total arsenic collected was 2.7 mg. The filter frit support ruptured approximately 14 minutes into the test and sampling was immediately terminated. The train was disassembled and recovered according to routine procedures. No significant amount of arsenic was present in the back half of the train in this run, and since the concentration is comparable with the within-run data, the sample run is considered representative. Because only 0.292 dsm<sup>3</sup> was metered, however, the sample volume does not conform to Method 108 specifications; therefore, the concentration value is not included in the group statistical data presented in Table 2-4.

The statistical data presented in Table 2-3 are comparable with data obtained during the EMSL-QAD portion of this test project. Statistical data for nine Method 108 quad train runs (36 individual samples; 121°C sample temperature) showed an overall mean of 9.59 mg/dsm<sup>3</sup> with mean arsenic concentrations of individual quad runs ranging from 8.48 to 10.55 mg/dsm<sup>3</sup>. The standard deviations of the EMSL tests ranged from 0.10 to 1.45 mg/dsm<sup>3</sup> with a pooled mean value of 0.59 mg/dsm<sup>3</sup>. The mean relative standard deviation (RSD) for the nine runs was 6.14 percent. Table 2-4 summarizes the EMSL quad train results.

The standard deviations of the elevated temperature quad runs ranged from 0.124 to 0.617 mg/dsm<sup>3</sup> with a pooled mean value of 0.367 mg/dsm<sup>3</sup>. The RSD values ranged from 1.4 to 6.9 percent with a mean RSD of 4.2 percent. The mean arsenic concentration of the individual quad runs ranged from 8.20 to 9.72 mg/dsm<sup>3</sup> with

TABLE 2-4. STATISTICAL DATA FOR GROUPED RUNS - EMSL QUAD TRAIN TESTS

Quad run No.	Concentration, mg/dsm <sup>3</sup>		$\sigma$ , <sup>b</sup> mg/dsm <sup>3</sup>	RSD, <sup>c</sup> %
	Individual run value	Group mean $\bar{x}$ <sup>a</sup>		
1A	9.11	8.48	1.45	17.1
1B	8.87			
1C	6.35			
1D	9.58			
2A	8.82	9.34	0.514	5.5
2B	10.05			
2C	9.22			
2D	9.28			
3A	9.26	9.92	0.446	4.5
3B	10.24			
3C	10.13			
3D	10.04			
4A	9.53	9.18	0.334	3.6
4B	9.28			
4C	8.73			
4D	9.17			
5A	10.62	10.55	0.10	0.95
5B	10.53			
5C	10.62			
5D	10.42			
6A	9.93	10.07	0.272	2.7
6B	9.96			
6C	9.92			
6D	10.48			
7A	9.57	9.62	0.361	3.8
7B	9.13			
7C	9.95			
7D	9.82			

(continued)

TABLE 2-4 (continued)

Quad run No.	Concentration, mg/dsm <sup>3</sup>		$\sigma$ , <sup>b</sup> mg/dsm <sup>3</sup>	RSD, <sup>c</sup> %
	Individual run value	Group mean $\bar{x}$ <sup>a</sup>		
8A	10.24	9.80	0.365	3.7
8B	9.95			
8C	9.44			
8D	9.57			
9A	9.06	9.32	0.305	3.3
9B	9.21			
9C	9.24			
9D	9.76			
Overall means	-	9.59 <sup>d</sup>	0.589 <sup>e</sup>	6.14 <sup>f</sup>

<sup>a</sup>Mean concentration.

<sup>b</sup>Within-run standard deviation with N-1 weighting for sample data.

<sup>c</sup>Within-run relative standard deviation is the standard deviation expressed as a percent of the mean concentration.

<sup>d</sup>Simple averages of tabulated data.

<sup>e</sup>Pooled standard deviation;  $\sqrt{\frac{\sum \sigma^2}{n}}$

<sup>f</sup> $\overline{\text{RSD}} = \sqrt{\frac{\sum \sigma^2}{n}} / \bar{x}$ .

an overall mean of 8.74 mg/dsm<sup>3</sup>. The overall mean of the elevated temperature runs compares to within 10 percent of the overall mean of the EMSL quad runs.

As shown in Table 2-2, the Method 108 reference train tests that ran concurrently with the quad train tests are comparable relative to total arsenic concentration and distribution. Overall, there is less than a 10 percent difference between the quad run means and the reference train arsenic concentrations. In Run 10, the quad group mean was 8.89 mg/dsm<sup>3</sup> compared with the reference train value of 8.70 mg/dsm<sup>3</sup>. In Run 11, the quad group mean excluding 11D was 8.47 mg/dsm<sup>3</sup> and the reference train value was 9.31 mg/dsm<sup>3</sup>. The group mean in Run 12 excluding 12D was 8.68 mg/dsm<sup>3</sup> and the reference train value was 7.78 mg/dsm<sup>3</sup>. In Run 13, the quad group mean was 8.91 mg/dsm<sup>3</sup> compared with 9.42 mg/dsm<sup>3</sup> for the reference train.

These data in conjunction with the EMSL quad run data suggest no significant difference between arsenic concentrations measured by Method 108 (121°C) and modified Method 108 (elevated sample temperature) at this source. The data also indicate no significant difference between samples collected at 204°C and those collected at 288°C.

Several factors observed during this test series that could have affected sample results are addressed as follows. The filter frit supports for Quad Runs 11D and 12C and 12D ruptured during testing. The ruptures were attributed to the deterioration of the silica rubber gasket due to the sample temperature

(288°C) and subsequent failure under vacuum. As mentioned in Subsection 2.2, Run 11D was not terminated when the gasket failed; consequently, a significant amount of arsenic was found in the back half of the sampling train. The arsenic measured by Train 11D, however, did not compare with the within-run samples on a total weight basis. Because particulate was noticeable on the frit, it was rinsed with 0.1 N NaOH into the container holding the contents of the first two impingers. Sample fractions from this run were reanalyzed and rechecked; no discrepancies were found in the reported analytical data.

Runs 12C and 12D were terminated immediately upon rupture of the frit. In Train 12C, the rupture occurred with less than one minute to go in the 70-minute test; in Train 12D, the rupture occurred approximately 14 minutes after the start of the test. In each case, no significant amount of arsenic was found in the back half of the train. Also, the arsenic concentrations determined in these two runs are comparable with the within-run data. New filter frits were used in each quad run, thereby minimizing this problem.

Several back-half samples (connector glassware and backup filters) from Quad Runs 10, 11, and 12 were contaminated by a brown, oily substance believed to be volatilized probe heat tape glue. This phenomenon is attributed to the high temperatures to which the probes were heated and the use of an asbestos string gasket material at the nozzle end of the probe. When heated to 288°C, the heat tape used in the construction of the probe heating system burned resulting in the volatilization of the tape



glue. A visual inspection of the affected probes showed a heavy deposit of contaminant on the asbestos gaskets as well as distinct trails of the contaminant on the nozzle end of the glass liner.

A heavier disposition of the contaminate was observed on the trains heated to 288°C than those heated to 204°C. The material was recovered by using the 0.1 N NaOH rinse and a nylon brush for each affected sample fraction. Since the material was recovered and digested according to Method 108 in a Parr bomb, any arsenic from the gas stream that might become bound to the material would be analyzed thus precluding a low bias on sample results. As the back-half results indicate (Table 2-2), no arsenic was found in these "contaminated" sample fraction; thus any bias in arsenic measurements is believed to be minimal.

Another phenomenon associated with the filter frit support occurred during the 288°C runs. Experiments conducted in our laboratory showed that the standard glass frit filter support with a silicon rubber gasket could withstand temperatures up to 260°C.

Above 260°C, deterioration of the gasket was noticeable as evidenced by a light film of material on the filter holder glassware. The material was believed to be a form of silicon oxide. This same white material was present on all of the 288°C filter glassware. A recovered sample from the laboratory experiment was analyzed for arsenic. A detection limit of 0.003 milligrams per liter was established for this sample and no detectable arsenic was found. The data indicate that this material would not cause

a high bias in arsenic results from these runs. Since the material is recoverable and would be digested in a Parr bomb, any arsenic from the gas stream which might become bound to the material would be analyzed thus precluding a low bias on sample results.

### 2.3 METHOD 108 TRAVERSE TEST RESULTS

Table 2-5 summarizes the sample and flue gas conditions and Table 2-6 presents the arsenic emissions data for the Method 108 traverse tests.

Triplicate tests were conducted at the completion of the quad train runs following procedures described in Method 108. Twenty-four traverse points (12 per port) were used to traverse the cross-sectional area of the stack. Each point was sampled for 2.5 minutes yielding a total test time of 60 minutes.

Sample volumes for the three tests were consistent and ranged from 1.03 to 1.07 dsm<sup>3</sup>. Isokinetic samples rates ranged from 100.3 to 105.6 percent. The flue gas volumetric flow in actual cubic meters per minute (m<sup>3</sup>/min) averaged 886 m<sup>3</sup>/min (440 dsm<sup>3</sup>/min at 20°C and 760 mmHg). The gas temperature and moisture content averaged 254°C and 8.0 percent, respectively. Flue gas composition was determined by analyzing integrated bag samples collected during each test with an Orsat gas analyzer. Oxygen (O<sub>2</sub>), carbon dioxide (CO<sub>2</sub>), and carbon monoxide (CO) contents averaged 13.9, 3.8, and 0.0 percent, respectively.

As presented in Table 2-6, the total arsenic catch in milligrams ranged from 8.67 mg for Test CD-3 to 9.65 mg for Test CD-2.

TABLE 2-5. SUMMARY OF SAMPLE AND FLUE GAS CONDITIONS  
ARSENIC TRAVERSE TESTS

Run No.	Date (1984)	Metered volume, dsm <sup>3</sup>	Moisture content, %	Stack gas tempera- ture, °C	Gas composition, <sup>a</sup> %			Volumetric <sup>b</sup> flow rate		Isoki- netic, %
					O <sub>2</sub>	CO <sub>2</sub>	CO	m <sup>3</sup> /min	dsm <sup>3</sup> /min	
CD-1	5/19	1.03	8.0	260	14.8	3.2	0.0	851	418	105.6
CD-2	5/19	1.06	8.3	255	12.1	4.7	0.0	903	446	102.1
CD-3	5/19	1.07	7.7	248	14.8	3.5	0.0	903	455	100.3
Average		1.05	8.0	254	13.9	3.8	0.0	886	440	-

<sup>a</sup>Gas composition determined using an Orsat gas analyzer.

<sup>b</sup>Volumetric flow rate in actual cubic meters per minute (m<sup>3</sup>/min) and dry standard cubic meters per minute (dsm<sup>3</sup>/min).

TABLE 2-6. SUMMARY OF ARSENIC ANALYTICAL RESULTS  
TRAVERSE TRAIN

Run No.	Metered volume, dsm <sup>3</sup>	Sample weight, mg Total arsenic	Concentra- tion, mg/dsm <sup>3</sup>	Mass emission rate, kg/h
CD-1	1.03	9.60	9.32	0.23
CD-2	1.06	9.65	9.10	0.24
CD-3	1.07	8.67	8.10	0.22
Average		9.31	8.84	0.23

Total arsenic concentration averaged 8.84 mg/dsm<sup>3</sup> with a corresponding average mass emission rate of 0.23 kilograms per hour (kg/h). These average results obtained by multipoint, isokinetic traverse techniques are comparable to results obtained during the quad train runs.

#### 2.4 PROCESS SAMPLES

Several finished glass samples were obtained during the test program to determine the arsenic content on a weight basis. Table 2-7 summarizes the process sample results. Results were consistent and the arsenic content by weight was approximately 0.05 percent. The samples analyzed were drinking mugs and three portions of each mug (top, handle, and bottom) were analyzed. Initially, glass chunks from the three sample fractions were placed in Teflon bombs and digested using the Parr bomb procedure from EPA Method 108. After extended heating, the glass chunks did not dissolve. Additional glass fragments were ground in an agate mortar and pestle and the resulting powder was placed in Teflon bombs and digested per the Method 108 Parr bomb procedure. After extended heating, a white precipitate remained in the bomb. The sample was filtered through a Teflon filter and the filtrate was analyzed for arsenic per Method 108. The remaining precipitate was gelatinous in nature rather than a dense powder of the original sample. The precipitate was redigested using a Parr bomb and the resulting solution was analyzed for arsenic per

TABLE 2-7. PROCESS SAMPLE ANALYTICAL RESULTS

Sample type	Lab No.	Description	Total arsenic, % by weight
Drinking mug	DM924	5/14; #2535 (handle)	0.052
	DM924	5/14; #2535 (top)	0.055
	DM924	5/14; #2535 (bottom)	0.059
Drinking mug	DM929	5/19; #2540 (handle)	0.055
	DM929	5/19; #2540 (top)	0.059
	DM929	5/19; #2540 (bottom)	0.055
	DM929R	5/19; \$2540 (bottom)	0.058

Method 108. This fraction consistently contained approximately 1 percent of the amount of arsenic found in the original filtrate. These numbers were combined and reported.

### SECTION 3

#### PROJECT QUALITY ASSURANCE

Because the desired end product of testing is to achieve representative emission results, quality assurance is one of the main facets of stack sampling. Quality assurance guidelines provide the detailed procedures and actions necessary for defining and producing acceptable data. Five such documents were used in this test program to ensure the collection of acceptable data and to provide a definition of unacceptable data. The following documents comprise the Quality Assurance Project Plan prepared by PEI and reviewed and approved by the Environmental Monitoring Support Laboratory of the EPA (see Volume II - Appendix F); the detailed site test plan prepared by PEI and reviewed by the Emission Measurement Branch; the EPA Quality Assurance Handbook Volume III, EPA-600/4-77-027; the PEI Emission Test Quality Assurance Plan; and the PEI Laboratory Quality Assurance Plan. The last two, which are PEI's general guideline manuals, define the company's standard operating procedures and are followed by the emission testing and laboratory groups.

In this specific test program, the following steps were taken to ensure that the testing and analytical procedures produced quality data.



- Calibration of all field sampling equipment.
- Checks on train configuration and calculations.
- Onsite quality assurance checks (i.e., leak checks of the sampling train, pitot tube, and Orsat line) and quality assurance checks of all test equipment prior to use.
- Use of designated analytical equipment and sampling reagents.
- Internal and external audits to ensure accuracy in sampling and analysis.

Table 3-1 lists the sampling equipment used to perform the arsenic tests and the calibration guidelines and limits. In addition to the pre- and post-test calibrations, a field audit was performed on the metering systems and thermocouple digital indicators used in the sample runs. PEI-constructed critical orifices were used in the dry gas meter audits. The onsite audits were made at the beginning, middle, and end of the test program. Figures 3-1 through 3-23 present the results of the pre-test, mid-test, and post-test onsite audits. These data were used to assess the operational status of the sampling equipment relative to guidelines established by the U.S. EPA. The results of the three field audits indicate that the sample equipment was functioning properly throughout this test series.

Figure 3-24 is an example of an unacceptable meter box audit. The audit value for the meter coefficient deviation was greater than  $\pm 5$  percent, which was considered unacceptable by the PEI Project Manager; therefore, the meter box was not used for this test program.

TABLE 3-1. FIELD EQUIPMENT CALIBRATION

Equipment	ID No.	Calibrated against	Allowable error	Actual error	Within allowable limits	Comments
Meter box	FB-1 Train A	Wet test meter	Y ±0.02 Y ΔH @ ±0.15 (Y ±0.05 Y post-test)	0.004	X	
				0.09	X	
				+1.35	X	
	FB-5 Train B			0.002	X	
				0.05	X	
				+0.10	X	
	FB-8 Train D			0.006	X	
				0.07	X	
				-0.20	X	
	FB-10 Train C			0.012	X	
				0.07	X	
				-0.52	X	
	FB-9 (Traverse tests)			0.013	X	
				0.08	X	
FB-9 (Reference train tests)	+1.30	X				
Pitot tube	513	Standard pitot tube	Cp ±0.01	-	OK	Visually inspected on site
	514			-	OK	
	508			-		
Digital indicator	220	Millivolt signals	0.5%	0.2%	X	
	221			0.4%	X	
Thermocouple	411 - (stack)	ASTM-3F	1.5% (±2% saturated)	0.4%	X	
	412 - (stack)			0.2%	X	
	601 - Probe			0.8%	X	
	605 - Filter			1.0%	X	

(continued)

TABLE 3-1 (continued)

Equipment	ID No.	Calibrated against	Allowable error	Actual error	Within allowable limits	Comments
3-4 Thermocouple (cont'd)	614 - Probe			0.4%	X	
	615 - Probe			0.6%	X	
	616 - Probe			0.5%	X	
	618 - Probe			0.6%	X	
	619 - Probe			0.6%	X	
	620 - Filter			1.2%	X	
Orsat analyzer	141	Standard gas	±0.5%	0.0%	X	CO <sub>2</sub> O <sub>2</sub> CO
				0.2%	X	
				0.0%	X	
Impinger thermometer	433	ASTM-3F	±2°F	1.2°F	X	
	434			0.5°F	X	
	435			1.0°F	X	
	446			1.0°F	X	
	385			1.0°F	X	
Mettler balance	M-1	Type S weights	±0.5 g	+0.1 g	X	
Barometer	407	NBS traceable barometer	+0.10 in.Hg. (0.20 post-test)	0.01 in.Hg.	X	
Dry gas thermometer	FB-1	ASTM-3F	±5°F	4°F	X	Inlet
				5°F	X	Outlet
	FB-5			4°F	X	Inlet
				2°F	X	Outlet
	FB-8			2°F	X	Inlet
				3°F	X	Outlet

(continued)

TABLE 3-1 (continued)

Equipment	ID No.	Calibrated against	Allowable error	Actual error	Within allowable limits	Comments
Dry gas thermometer (cont'd)	FB-10	Caliper	Dn $\pm 0.004$ in.	2°F	X	Inlet
				2°F	X	Outlet
	FB-9			2°F	X	Inlet
				2°F	X	Outlet
Probe nozzle	1A			0.001 in.	X	
	1B			0.002 in.	X	
	1C			0.000 in.	X	
	1D			0.001 in.	X	
	2A			0.002 in.	X	
	2B			0.002 in.	X	
	2C			0.000 in.	X	
	2D			0.002 in.	X	
	5-106 (RT tests)			0.001 in.	X	
	2-117 (Traverse tests)			0.003 in.	X	

**FIELD AUDIT REPORT: DRY GAS METER  
BY CRITICAL ORIFICE**

DATE: 5-11-84

CLIENT: USEPA-QAD

BAROMETRIC PRESSURE ( $P_{bar}$ ): 29.00 in.Hg

METER BOX NO. FB 1-Train A

ORIFICE NO. 6

PRETEST Y: 0.965  $\Delta H@$  1.72 in.H<sub>2</sub>O

ORIFICE K FACTOR:  $5.241 \times 10^{-4}$

AUDITOR: David E. Baggett

Orifice manometer reading $\Delta H$ , in.H <sub>2</sub> O	Dry gas meter reading $V_i/V_f$ , ft <sup>3</sup>	Temperatures					Duration of run $\emptyset$ min.
		Ambient		Dry gas meter			
		$T_{ai}/T_{af}$ , °F	Average $T_a$ , °F	Inlet $T_{ii}/T_{if}$ , °F	Outlet $T_{oi}/T_{of}$ , °F	Average $T_m$ , °F	
2.05	894.500 909.200	68 70	69	72 72	64 65	68.25	17 <sup>12.3</sup> / <sub>60</sub>

Dry gas meter $V_m$ , ft <sup>3</sup>	$V_{mstd}$ , ft <sup>3</sup>	$V_{mact}$ , ft <sup>3</sup>	Audit, Y	Y deviation, %	Audit $\Delta H@$ , in.H <sub>2</sub> O	$\Delta H@$ Devia- tion, in.H <sub>2</sub> O
14.700	14.315	13.673	0.955	1.05	1.72	0.0

$$V_{mstd} = \frac{17.647(V_m)(P_{bar} + \Delta H/13.6)}{(T_m + 460)} = 14.315 \text{ ft}^3$$

$$V_{mact} = \frac{1203(\emptyset)(K)(P_{bar})}{(T_a + 460)^{1/2}} = 13.673 \text{ ft}^3$$

$$\text{Audit Y} = \frac{V_{mact}}{V_{mstd}} = 0.955 \quad \text{Y deviation} = \frac{\text{Audit Y} - \text{Pre-test Y}}{\text{Audit Y}} \times 100 = 1.05$$

$$\text{Audit } \Delta H@ = (0.0317)(\Delta H)(P_{bar})(T_m + 460) \left[ \frac{\emptyset}{Y(V_m)(P_{bar} + \Delta H/13.6)} \right]^2 = 1.72 \text{ in.H}_2\text{O}$$

Audit Y must be in the range, pre-test Y  $\pm 0.05$  Y.

Audit  $\Delta H@$  must be in the range pre-test  $\Delta H@ \pm 0.15$  inches H<sub>2</sub>O.

Figure 3-1. Pre-test audit report: dry gas meter by  
critical orifice (Meter Box FB-1, Train A).

**FIELD AUDIT REPORT: DRY GAS METER  
BY CRITICAL ORIFICE**

DATE: 5-11-84

CLIENT: USEPA-QAD

BAROMETRIC PRESSURE ( $P_{bar}$ ): 29.00 in.Hg

METER BOX NO. FB 5-Train B

ORIFICE NO. 3

PRETEST Y: 0.983  $\Delta H@$  1.84 in.H<sub>2</sub>O

ORIFICE K FACTOR:  $5.377 \times 10^{-4}$

AUDITOR: David E. Fitzgerald

Orifice manometer reading $\Delta H$ , in. H <sub>2</sub> O	Dry gas meter reading $V_i/V_f$ , ft <sup>3</sup>	Temperatures					Duration of run $\emptyset$ min.
		Ambient		Dry gas meter			
		$T_{ai}/T_{af}$ , °F	Average $T_a$ , °F	Inlet $T_{ii}/T_{if}$ , °F	Outlet $T_{oi}/T_{of}$ , °F	Average $T_m$ , °F	
2.25	248.700	70	70	79	75	77.5	17 <sup>3.2</sup> / <sub>60</sub>
	263.600	70		80	76		

Dry gas meter $V_m$ , ft <sup>3</sup>	$V_{mstd}$ , ft <sup>3</sup>	$V_{mact}$ , ft <sup>3</sup>	Audit, Y	Y deviation, %	Audit $\Delta H@$ , in.H <sub>2</sub> O	$\Delta H@$ Deviation, in.H <sub>2</sub> O
14.900	14.267	13.892	0.974	-0.92	1.77	0.07

$$V_{mstd} = \frac{17.647(V_m)(P_{bar} + \Delta H/13.6)}{(T_m + 460)} = 14.267 \text{ ft}^3$$

$$V_{mact} = \frac{1203(\emptyset)(K)(P_{bar})}{(T_a + 460)^{1/2}} = 13.892 \text{ ft}^3$$

$$\text{Audit Y} = \frac{V_{mact}}{V_{mstd}} = 0.974 \quad Y \text{ deviation} = \frac{\text{Audit Y} - \text{Pre-test Y}}{\text{Audit Y}} \times 100 = -0.92$$

$$\text{Audit } \Delta H@ = (0.0317)(\Delta H)(P_{bar})(T_m + 460) \left[ \frac{\emptyset}{Y(V_m)(P_{bar} + \Delta H/13.6)} \right]^2 = 1.77 \text{ in.H}_2\text{O}$$

Audit Y must be in the range, pre-test Y  $\pm 0.05$  Y.  
Audit  $\Delta H@$  must be in the range pre-test  $\Delta H@ \pm 0.15$  inches H<sub>2</sub>O.

Figure 3-2. Pre-test audit report: dry gas meter by critical orifice (Meter Box FB-5, Train B).

**FIELD AUDIT REPORT: DRY GAS METER  
BY CRITICAL ORIFICE**

DATE: 5-11-84  
 BAROMETRIC PRESSURE ( $P_{bar}$ ): 29.00 in.Hg  
 ORIFICE NO. 3  
 ORIFICE K FACTOR:  $5.377 \times 10^{-4}$

CLIENT: USEPA-QAD  
 METER BOX NO. FB 8 - Train D  
 PRETEST Y: 0.990  $\Delta H@$  1.91 in.H<sub>2</sub>O  
 AUDITOR: Daniel E. Fitzgerald

Orifice manometer reading $\Delta H$ ,  in.H <sub>2</sub> O	Dry gas meter reading $V_i/V_f$ ,  ft <sup>3</sup>	Temperatures					Duration of run $\emptyset$ min.
		Ambient		Dry gas meter			
		$T_{ai}/T_{af}$ ,  °F	Average $T_a$ ,  °F	Inlet $T_{ii}/T_{if}$ ,  °F	Outlet $T_{oi}/T_{of}$ ,  °F	Average $T_m$ ,  °F	
2.30	414.300	72	72	73	69	71.5	15 $\frac{26.2}{60}$
	427.500	72		74	70		

Dry gas meter $V_m$ , ft <sup>3</sup>	$V_{mstd}$ , ft <sup>3</sup>	$V_{mact}$ , ft <sup>3</sup>	Audit, Y	Y devia- tion, %	Audit $\Delta H@$ , in.H <sub>2</sub> O	$\Delta H@$ Devia- tion, in.H <sub>2</sub> O
13.200	12.784	12.577	0.982	0.81	1.84	0.07

$$V_{mstd} = \frac{17.647(V_m)(P_{bar} + \Delta H/13.6)}{(T_m + 460)} = 12.784 \text{ ft}^3$$

$$V_{mact} = \frac{1203(\emptyset)(K)(P_{bar})}{(T_a + 460)^{1/2}} = 12.557 \text{ ft}^3$$

$$\text{Audit } Y = \frac{V_{mact}}{V_{mstd}} = 0.982 \quad Y \text{ deviation} = \frac{\text{Audit } Y - \text{Pre-test } Y}{\text{Audit } Y} \times 100 = 0.81$$

$$\text{Audit } \Delta H@ = (0.0317)(\Delta H)(P_{bar})(T_m + 460) \left[ \frac{\emptyset}{Y(V_m)(P_{bar} + \Delta H/13.6)} \right]^2 = 1.84 \text{ in.H}_2\text{O}$$

Audit Y must be in the range, pre-test Y  $\pm 0.05$  Y.  
 Audit  $\Delta H@$  must be in the range pre-test  $\Delta H@ \pm 0.15$  inches H<sub>2</sub>O.

Figure 3-3. Pre-test audit report: dry gas meter by  
critical orifice (Meter Box FB-8, Train D).

**FIELD AUDIT REPORT: DRY GAS METER  
BY CRITICAL ORIFICE**

DATE: 5-11-84

CLIENT: USEPA - QAD

BAROMETRIC PRESSURE ( $P_{bar}$ ): 29.00 in.Hg

METER BOX NO. FB 10 - Train C

ORIFICE NO. 12

PRETEST Y: 1.967  $\Delta H$  1.81 in.H<sub>2</sub>O

ORIFICE K FACTOR:  $4.795 \times 10^{-4}$

AUDITOR: David E. Fitzgerald

Orifice manometer reading $\Delta H$ ,  in.H <sub>2</sub> O	Dry gas meter reading $V_i/V_f$ ,  ft <sup>3</sup>	Temperatures					Duration of run $\emptyset$ min.
		Ambient		Dry gas meter			
		$T_{ai}/T_{af}$ ,  °F	Average $T_a$ ,  °F	Inlet $T_{ii}/T_{if}$ ,  °F	Outlet $T_{oi}/T_{of}$ ,  °F	Average $T_m$ ,  °F	
1.80	020.900	70	70.5	76	72	74.75	21 <sup>19.0</sup> / <sub>60</sub>
	037.900	71		77	74		

Dry gas meter $V_m$ , ft <sup>3</sup>	$V_{mstd}$ , ft <sup>3</sup>	$V_{mact}$ , ft <sup>3</sup>	Audit, Y	Y deviation, %	Audit $\Delta H$ , in.H <sub>2</sub> O	$\Delta H$ Deviation, in.H <sub>2</sub> O
<u>17.000</u>	<u>16.343</u>	<u>15.484</u>	<u>0.947</u>	<u>-2.1</u>	<u>1.75</u>	<u>0.06</u>

$$V_{mstd} = \frac{17.647(V_m)(P_{bar} + \Delta H/13.6)}{(T_m + 460)} = 16.343 \text{ ft}^3$$

$$V_{mact} = \frac{1203(\emptyset)(K)(P_{bar})}{(T_a + 460)^{1/2}} = 15.484 \text{ ft}^3$$

$$\text{Audit Y} = \frac{V_{mact}}{V_{mstd}} = 0.947 \quad Y \text{ deviation} = \frac{\text{Audit Y} - \text{Pre-test Y}}{\text{Audit Y}} \times 100 = -2.1$$

$$\text{Audit } \Delta H = (0.0317)(\Delta H)(P_{bar})(T_m + 460) \left[ \frac{\emptyset}{Y(V_m)(P_{bar} + \Delta H/13.6)} \right]^2 = 1.75 \text{ in.H}_2\text{O}$$

Audit Y must be in the range, pre-test Y  $\pm 0.05$  Y.

Audit  $\Delta H$  must be in the range pre-test  $\Delta H \pm 0.15$  inches H<sub>2</sub>O.

Figure 3-4. Pre-test audit report: dry gas meter by critical orifice (Meter Box FB-10, Train C).



FIELD AUDIT REPORT: DRY GAS METER  
BY CRITICAL ORIFICE

DATE: 5-16-84

CLIENT: USEPA-

BAROMETRIC PRESSURE ( $P_{bar}$ ): 29.52 in.Hg

METER BOX NO. FB#9 (Single Pt. & Traverse Tests)

ORIFICE NO. #7

PRETEST Y: 0.980  $\Delta H@$  2.07 in.H<sub>2</sub>O

ORIFICE K FACTOR:  $4.964 \times 10^{-4}$

AUDITOR: Kenneth E. Rogers

Orifice manometer reading $\Delta H$ ,  in.H <sub>2</sub> O	Dry gas meter reading $V_i/V_f$ ,  ft <sup>3</sup>	Temperatures					Duration of run $\phi$ min.
		Ambient		Dry gas meter			
		$T_{ai}/T_{af}$ ,  °F	Average $T_a$ ,  °F	Inlet $T_{ii}/T_{if}$ ,  °F	Outlet $T_{oi}/T_{of}$ ,  °F	Average $T_m$ ,  °F	
2.25	023.000	72	73.0	82	72	78.5	25 <sup>1.9</sup> <sub>60</sub>
	043.200	<del>74.80</del>		84	76		

Dry gas meter $V_m$ , ft <sup>3</sup>	$V_{mstd}$ , ft <sup>3</sup>	$V_{mact}$ , ft <sup>3</sup>	Audit, Y	Y deviation, %	Audit $\Delta H@$ , in.H <sub>2</sub> O	$\Delta H@$ Deviation, in.H <sub>2</sub> O
20.2	20.123	19.112	0.950	-3.15	2.05	0.02

$$V_{mstd} = \frac{17.647(V_m)(P_{bar} + \Delta H/13.6)}{(T_m + 460)} = 20.123 \text{ ft}^3$$

$$V_{mact} = \frac{1203(\phi)(K)(P_{bar})}{(T_a + 460)^{1/2}} = 19.112 \text{ ft}^3$$

$$\text{Audit Y} = \frac{V_{mact}}{V_{mstd}} = 0.950 \quad Y \text{ deviation} = \frac{\text{Audit Y} - \text{Pre-test Y}}{\text{Audit Y}} \times 100 = -3.15$$

$$\text{Audit } \Delta H@ = (0.0317)(\Delta H)(P_{bar})(T_m + 460) \left[ \frac{\phi}{Y(V_m)(P_{bar} + \Delta H/13.6)} \right]^2 = 2.05 \text{ in.H}_2\text{O}$$

Audit Y must be in the range, pre-test Y  $\pm 0.05$  Y.  
Audit  $\Delta H@$  must be in the range pre-test  $\Delta H@ \pm 0.15$  inches H<sub>2</sub>O.

Figure 3-5. Pre-test audit report: dry gas meter by critical orifice (Meter Box FB-9, Single Point-Traverse Tests).

**THERMOCOUPLE DIGITAL INDICATOR  
AUDIT DATA SHEET**

Date 5-11-84 Indicator No. 220 Operator Ref

Test Point No.	Millivolt signal*	Equivalent temperature, °F*	Digital indicator temperature reading, °F	Difference, %
1		32	32	0.0
2		200	202	-0.30
3		540	540	0.0
4		1194	1196	-0.12

Percent difference must be less than or equal to 0.5%.

Percent difference:


$$\frac{(\text{Equivalent temperature } ^\circ\text{R} - \text{Digital indicator temperature reading } ^\circ\text{R})(100\%)}{(\text{Equivalent temperature } ^\circ\text{R})}$$

Where  $^\circ\text{R} = ^\circ\text{F} + 460^\circ\text{F}$

\* These values are to be obtained from the calibration data sheet for the calibration device.

Figure 3-6. Pre-test thermocouple digital indicator audit data sheet (Indicator No. 220).

**THERMOCOUPLE DIGITAL INDICATOR  
AUDIT DATA SHEET**

Date 5-11-84 Indicator No. 221 Operator 

Test Point No.	Millivolt signal*	Equivalent temperature, °F*	Digital indicator temperature reading, °F	Difference, %
1		32	30	0.41
2		200	201	-0.15
3		540	540	0.00
4		1194	1196	-0.12

Percent difference must be less than or equal to 0.5%.

Percent difference:

$$\frac{(\text{Equivalent temperature } ^\circ\text{R} - \text{Digital indicator temperature reading } ^\circ\text{R})(100\%)}{(\text{Equivalent temperature } ^\circ\text{R})}$$

Where  $^\circ\text{R} = ^\circ\text{F} + 460^\circ\text{F}$

\* These values are to be obtained from the calibration data sheet for the calibration device.

Figure 3-7. Pre-test thermocouple digital indicator audit data sheet (Indicator No. 221).

# ON-SITE AUDIT DATA SHEET

Audit Name: INDIANA GLASS

Date: 5-11-84

Auditor: [Signature]

Equipment	Reference	Reference Value	Value Determined	Deviation	Max. Allowable Deviation
FB2 FB1 FB5 Meter box inlet thermo.	ASTM-3F at ambient temp.	68 68 68	71 66 72	3 2 4	5°F
FB2 FB1 FB5 Meter box outlet thermo.	ASTM-3F at ambient temp.	68 68 68	71 62 70	3 4 2	5°F
446 434 Impinger thermometer	ASTM-3F at ambient temp.	66 66	64 67	2 1	2°F
AF 613 <del>stack</del> BF 605 <del>thermometer</del> EF 610 <del>or FILTER</del> DF 620 Thermocouple	ASTM-3F at ambient temp.	70 70	68 68	2 2	7°F
	ASTM-3F at <del>stack temp.</del>	70 70	67 67	3 3	See table
Orsat analyzer	% O <sub>2</sub> in ambient air	20.8%			0.7%
Trip balance	IOLM std. weight	NA	NA	NA	0.5 grams
Barometer	Corrected* NWS value				0.20 in. Hg

Reference temp. °F	32-140	141-273	274-406	407-540	541-673	674-760
Max. deviation °F	7	9	11	13	15	17

\* Correction factor:

NWS value (in. Hg) - [Altitude (ft)/1000(ft/in. Hg)] + 0.74 in. Hg\*\*

\*\* 0.74 in. Hg is the nominal correction factor for the reference barometer against which the field barometer was calibrated.

If it is not feasible to perform the audit on any piece of equipment, record "N/A" in the space provided for the data.

Figure 3-8. Pre-test onsite audit data sheet.

# ON-SITE AUDIT DATA SHEET

Audit Name: INDIANA GLASS Date: 5-11-84 Auditor: [Signature]

Equipment	Reference	Reference Value	Value Determined	Deviation	Max. Allowable Deviation
FD <sup>10</sup> Meter box FB <sup>8</sup> inlet thermo.	ASTM-3F at ambient temp.	68 68	67 65	1 3	5°F
FD <sup>10</sup> Meter box FB <sup>8</sup> outlet thermo.	ASTM-3F at ambient temp.	68 68	66 64	2 4	5°F
433 Impinger 435 thermometer	ASTM-3F at ambient temp.	66 66	66 67	0 1	2°F
Stack thermometer or Thermocouple	ASTM-3F at ambient temp.				7°F
	ASTM-3F at stack temp.				See table
Orsat analyzer	% O <sub>2</sub> in ambient air	20.8%			0.7%
Trip balance	IOLM std. weight				0.5 grams
Barometer	Corrected* NWS value				0.20 in. Hg

Reference temp. °F	32-140	141-273	274-406	407-540	541-673	674-760
Max. deviation °F	7	9	11	13	15	17

\* Correction factor:

NWS value (in. Hg) - [Altitude (ft)/1000(ft/in. Hg)] + 0.74 in. Hg\*\*

\*\* 0.74 in. Hg is the nominal correction factor for the reference barometer against which the field barometer was calibrated.

If it is not feasible to perform the audit on any piece of equipment, record "N/A" in the space provided for the data.

Figure 3-9. Pre-test onsite audit data sheet.

**FIELD AUDIT REPORT: DRY GAS METER  
BY CRITICAL ORIFICE**

DATE: 5-16-84

CLIENT: USEPA-QAD

BAROMETRIC PRESSURE ( $P_{bar}$ ): 29.52 in.Hg

METER BOX NO. FB#1

ORIFICE NO. #3

PRETEST Y: 0.965  $\Delta H@$  1.72 in.H<sub>2</sub>O

ORIFICE K FACTOR:  $5.379 \times 10^{-4}$

AUDITOR: James E. Fitzgerald

Orifice manometer reading $\Delta H$ ,  in.H <sub>2</sub> O	Dry gas meter reading $V_i/V_f$ ,  ft <sup>3</sup>	Temperatures					Duration of run $\emptyset$ min.
		Ambient		Dry gas meter			
		$T_{ai}/T_{af}$ ,  °F	Average $T_a$ ,  °F	Inlet $T_{ii}/T_{if}$ ,  °F	Outlet $T_{oi}/T_{of}$ ,  °F	Average $T_m$ ,  °F	
2.20	261.900	69	69	83	78	79.5	15 <sup>54.0</sup> <sub>60</sub>
	276.200	69		80	77		

Dry gas meter $V_m$ , ft <sup>3</sup>	$V_{mstd}$ , ft <sup>3</sup>	$V_{mact}$ , ft <sup>3</sup>	Audit, Y	Y deviation, %	Audit $\Delta H@$ , in.H <sub>2</sub> O	$\Delta H@$ Deviation, in.H <sub>2</sub> O
14.300	13.884	13.200	0.951	-1.47	1.67	0.05

$$V_{mstd} = \frac{17.647(V_m)(P_{bar} + \Delta H/13.6)}{(T_m + 460)} = 13.884 \text{ ft}^3$$

$$V_{mact} = \frac{1203(\emptyset)(K)(P_{bar})}{(T_a + 460)^{1/2}} = 13.200 \text{ ft}^3$$

$$\text{Audit Y} = \frac{V_{mact}}{V_{mstd}} = 0.951 \quad Y \text{ deviation} = \frac{\text{Audit Y} - \text{Pre-test Y}}{\text{Audit Y}} \times 100 = -1.47$$

$$\text{Audit } \Delta H@ = (0.0317)(\Delta H)(P_{bar})(T_m + 460) \left[ \frac{\emptyset}{Y(V_m)(P_{bar} + \Delta H/13.6)} \right]^2 = 1.67 \text{ in.H}_2\text{O}$$

Audit Y must be in the range, pre-test Y  $\pm 0.05$  Y.

Audit  $\Delta H@$  must be in the range pre-test  $\Delta H@ \pm 0.15$  inches H<sub>2</sub>O.

Figure 3-10. Mid-test audit report: dry gas meter  
by critical orifice (Meter Box FB-1).

**FIELD AUDIT REPORT: DRY GAS METER  
BY CRITICAL ORIFICE**

DATE: 5-16-84 CLIENT: USEPA-QAD  
 BAROMETRIC PRESSURE ( $P_{bar}$ ): 29.52 in.Hg METER BOX NO. FB#5  
 ORIFICE NO. 7 PRETEST Y: 0.983  $\Delta H@$  1.84 in.H<sub>2</sub>O  
 ORIFICE K FACTOR:  $4.964 \times 10^{-4}$  AUDITOR: *James E. [Signature]*

Orifice manometer reading $\Delta H$ , in. H <sub>2</sub> O	Dry gas meter reading $V_i/V_f$ , ft <sup>3</sup>	Temperatures					Duration of run $\emptyset$ min.
		Ambient		Dry gas meter			
		$T_{ai}/T_{af}$ , °F	Average $T_a$ , °F	Inlet $T_{ii}/T_{if}$ , °F	Outlet $T_{oi}/T_{of}$ , °F	Average $T_m$ , °F	
2.10	638.500	70	70	98	92	93.75	16 <sup>42.4</sup> / <sub>60</sub>
	652.500	70		94	91		

Dry gas meter $V_m$ , ft <sup>3</sup>	$V_{mstd}$ , ft <sup>3</sup>	$V_{mact}$ , ft <sup>3</sup>	Audit, Y	Y deviation, %	Audit $\Delta H@$ , in.H <sub>2</sub> O	$\Delta H@$ Devia- tion, in.H <sub>2</sub> O
14.000	13.239	12.795	0.966	-1.76	1.82	0.02

$$V_{mstd} = \frac{17.647(V_m)(P_{bar} + \Delta H/13.6)}{(T_m + 460)} = 13.239 \text{ ft}^3$$

$$V_{mact} = \frac{1203(\emptyset)(K)(P_{bar})}{(T_a + 460)^{1/2}} = 12.795 \text{ ft}^3$$

$$\text{Audit } Y = \frac{V_{mact}}{V_{mstd}} = 0.966 \quad Y \text{ deviation} = \frac{\text{Audit } Y - \text{Pre-test } Y}{\text{Audit } Y} \times 100 = -1.76$$

$$\text{Audit } \Delta H@ = (0.0317)(\Delta H)(P_{bar})(T_m + 460) \left[ \frac{\emptyset}{V(V_m)(P_{bar} + \Delta H/13.6)} \right]^2 = 1.82 \text{ in.H}_2\text{O}$$

Audit Y must be in the range, pre-test Y  $\pm 0.05$  Y.  
 Audit  $\Delta H@$  must be in the range pre-test  $\Delta H@ \pm 0.15$  inches H<sub>2</sub>O.

Figure 3-11. Mid-test audit report: dry gas meter  
by critical orifice (Meter Box FB-5).

**FIELD AUDIT REPORT: DRY GAS METER  
BY CRITICAL ORIFICE**

DATE: 5-16-84 CLIENT: USEPA-QAD  
 BAROMETRIC PRESSURE ( $P_{bar}$ ): 29.52 in. Hg METER BOX NO. FB#8  
 ORIFICE NO. #6 PRETEST Y: 0.990  $\Delta H@$  1.91 in. H<sub>2</sub>O  
 ORIFICE K FACTOR:  $5.241 \times 10^{-4}$  AUDITOR: Kanish - J. J. General

Orifice manometer reading $\Delta H$ ,  in. H <sub>2</sub> O	Dry gas meter reading $V_i/V_f$ ,  ft <sup>3</sup>	Temperatures					Duration of run $\emptyset$ min.
		Ambient		Dry gas meter			
		$T_{ai}/T_{af}$ ,  °F	Average $T_a$ ,  °F	Inlet $T_{ii}/T_{if}$ ,  °F	Outlet $T_{oi}/T_{of}$ ,  °F	Average $T_m$ ,  °F	
2.25	777.000	69	69.5	88	86	87.25	15 <sup>45.3</sup> / <sub>60</sub>
	790.500	70		88	87		

Dry gas meter $V_m$ , ft <sup>3</sup>	$V_{mstd}$ , ft <sup>3</sup>	$V_{mact}$ , ft <sup>3</sup>	Audit, Y	Y deviation, %	Audit $\Delta H@$ , in. H <sub>2</sub> O	$\Delta H@$ Deviation, in. H <sub>2</sub> O
13500	12.923	12.747	0.986	0.40	1.82	0.09

$$V_{mstd} = \frac{17.647(V_m)(P_{bar} + \Delta H/13.6)}{(T_m + 460)} = 12.923 \text{ ft}^3$$

$$V_{mact} = \frac{1203(\emptyset)(K)(P_{bar})}{(T_a + 460)^{1/2}} = 12.747 \text{ ft}^3$$

$$\text{Audit } Y = \frac{V_{mact}}{V_{mstd}} = 0.986 \quad Y \text{ deviation} = \frac{\text{Audit } Y - \text{Pre-test } Y}{\text{Audit } Y} \times 100 = -0.40$$

$$\text{Audit } \Delta H@ = (0.0317)(\Delta H)(P_{bar})(T_m + 460) \left[ \frac{\emptyset}{Y(V_m)(P_{bar} + \Delta H/13.6)} \right]^2 = 1.82 \text{ in. H}_2\text{O}$$

Audit Y must be in the range, pre-test Y  $\pm 0.05$  Y.  
 Audit  $\Delta H@$  must be in the range pre-test  $\Delta H@ \pm 0.15$  inches H<sub>2</sub>O.

Figure 3-12. Mid-test audit report: dry gas meter  
by critical orifice (Meter Box FB-8).



**FIELD AUDIT REPORT: DRY GAS METER  
BY CRITICAL ORIFICE**

DATE: 5-16-84 CLIENT: USEPA-QAD  
 BAROMETRIC PRESSURE ( $P_{bar}$ ): 29.52 in.Hg METER BOX NO. FB# 10  
 ORIFICE NO. # 12 PRETEST Y: 0.967  $\Delta H@$  1.81 in.H<sub>2</sub>O  
 ORIFICE K FACTOR:  $4.795 \times 10^{-4}$  AUDITOR: James E. [Signature]

Orifice manometer reading $\Delta H$ , in.H <sub>2</sub> O	Dry gas meter reading $V_i/V_f$ , ft <sup>3</sup>	Temperatures					Duration of run $\emptyset$ min.
		Ambient		Dry gas meter			
		$T_{ai}/T_{af}$ , °F	Average $T_a$ , °F	Inlet $T_{ii}/T_{if}$ , °F	Outlet $T_{oi}/T_{of}$ , °F	Average $T_m$ , °F	
1.90	426.800	70	70	92	92	91.5	15 <sup>28.4</sup> <sub>00</sub>
	439.500	70		91	91		

Dry gas meter $V_m$ , ft <sup>3</sup>	$V_{mstd}$ , ft <sup>3</sup>	$V_{mact}$ , ft <sup>3</sup>	Audit, Y	Y deviation, %	Audit $\Delta H@$ , in.H <sub>2</sub> O	$\Delta H@$ Devia- tion, in.H <sub>2</sub> O
<u>12.700</u>	<u>12.053</u>	<u>11.442</u>	<u>0.949</u>	<u>-1.90</u>	<u>1.77</u>	<u>0.04</u>

$$V_{mstd} = \frac{17.647(V_m)(P_{bar} + \Delta H/13.6)}{(T_m + 460)} = 12.053 \text{ ft}^3$$

$$V_{mact} = \frac{1203(\emptyset)(K)(P_{bar})}{(T_a + 460)^{1/2}} = 11.442 \text{ ft}^3$$

$$\text{Audit Y} = \frac{V_{mact}}{V_{mstd}} = 0.949 \quad \text{Y deviation} = \frac{\text{Audit Y} - \text{Pre-test Y}}{\text{Audit Y}} \times 100 = -1.90$$

$$\text{Audit } \Delta H@ = (0.0317)(\Delta H)(P_{bar})(T_m + 460) \left[ \frac{\emptyset}{Y(V_m)(P_{bar} + \Delta H/13.6)} \right]^2 = 1.77 \text{ in.H}_2\text{O}$$

Audit Y must be in the range, pre-test Y  $\pm 0.05$  Y.  
 Audit  $\Delta H@$  must be in the range pre-test  $\Delta H@ \pm 0.15$  inches H<sub>2</sub>O.

Figure 3-13. Mid-test audit report: dry gas meter  
by critical orifice (Meter Box FB-10).

**THERMOCOUPLE DIGITAL INDICATOR  
AUDIT DATA SHEET**

Date 5-16-84 Indicator No. 220 Operator Ref

Test Point No.	Millivolt signal*	Equivalent temperature, °F*	Digital indicator temperature reading, °F	Difference, %
1		32	33	-.2
2		200	203	-.45
3		540	539	.1
4		1194	1194	0

Percent difference must be less than or equal to 0.5%.

Percent difference:

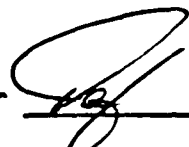
$$\frac{(\text{Equivalent temperature } ^\circ\text{R} - \text{Digital indicator temperature reading } ^\circ\text{R})(100\%)}{(\text{Equivalent temperature } ^\circ\text{R})}$$

Where  $^\circ\text{R} = ^\circ\text{F} + 460^\circ\text{F}$

\* These values are to be obtained from the calibration data sheet for the calibration device.

Figure 3-14. Mid-test thermocouple digital indicator audit data sheet (Indicator No. 220).

**THERMOCOUPLE DIGITAL INDICATOR  
AUDIT DATA SHEET**

Date 5-16-84 Indicator No. 221 Operator 

Test Point No.	Millivolt signal*	Equivalent temperature, °F*	Digital indicator temperature reading, °F	Difference, %
1		32	29	.61
2		200	199	.15
3		540	537	.3
4		1194	1193	.06

Percent difference must be less than or equal to 0.5%.

Percent difference:

$$\frac{(\text{Equivalent temperature } ^\circ\text{R} - \text{Digital indicator temperature reading } ^\circ\text{R})(100\%)}{(\text{Equivalent temperature } ^\circ\text{R})}$$

Where  $^\circ\text{R} = ^\circ\text{F} + 460^\circ\text{F}$

\* These values are to be obtained from the calibration data sheet for the calibration device.

Figure 3-15. Mid-test thermocouple digital indicator audit data sheet (Indicator No. 221).

# ON-SITE AUDIT DATA SHEET

Audit Name: INDIANA GLASS Date: 5-17-84 Auditor: [Signature]

Equipment	Reference	Reference Value	Value Determined	Deviation	Max. Allowable Deviation
FB10 Meter box inlet thermo.	ASTM-3F at ambient temp.	58	57	1	5°F
FB8 outlet thermo.	ASTM-3F at ambient temp.	58	56	2	5°F
FB10 Meter box outlet thermo.	ASTM-3F at ambient temp.	58	55	3	5°F
FB8 outlet thermo.	ASTM-3F at ambient temp.	58	55	3	5°F
433 Impinger thermometer	ASTM-3F at ambient temp.	64	64	0	2°F
434 Impinger thermometer	ASTM-3F at ambient temp.	64	62	2	2°F
Stack thermometer or Thermocouple	ASTM-3F at ambient temp.				7°F
	ASTM-3F at stack temp.				See table
Orsat analyzer	% O <sub>2</sub> in ambient air	20.8%			0.7%
Trip balance	IOLM std. weight	NA			0.5 grams
Barometer	Corrected* NWS value	NA			0.20 in. Hg

Reference temp. °F	32-140	141-273	274-406	407-540	541-673	674-760
Max. deviation °F	7	9	11	13	15	17

\* Correction factor:

NWS value (in. Hg) - [Altitude (ft)/1000(ft/in. Hg)] + 0.74 in. Hg\*\*

\*\* 0.74 in. Hg is the nominal correction factor for the reference barometer against which the field barometer was calibrated.

If it is not feasible to perform the audit on any piece of equipment, record "N/A" in the space provided for the data.

Figure 3-16. Mid-test onsite audit data sheet.

# ON-SITE AUDIT DATA SHEET

Audit Name: INDIANA GLASS Co Date: 5-17-84 Auditor: Ref

FB9  
FB1  
FB5  
FB9  
FB1  
FB5  
446  
435

Equipment	Reference	Reference Value	Value Determined	Deviation	Max. Allowable Deviation
Meter box inlet thermo.	ASTM-3F at ambient temp.	58 58 58	57 54 58	-1 4 0	5°F
Meter box outlet thermo.	ASTM-3F at ambient temp.	58 58 58	53 53 58	5 5 0	5°F
Impinger thermometer	ASTM-3F at ambient temp.	64 64	65 66	1 2	2°F
Stack thermometer or Thermocouple	ASTM-3F at ambient temp.				7°F
	ASTM-3F at stack temp.				See table
Orsat analyzer	% O <sub>2</sub> in ambient air	20.8%			0.7%
Trip balance	IOLM std. weight	NA			0.5 grams
Barometer	Corrected* NWS value	NA			0.20 in. Hg

Reference temp. °F	32-140	141-273	274-406	407-540	541-673	674-760
Max. deviation °F	7	9	11	13	15	17

\* Correction factor:

NWS value (in. Hg) - [Altitude (ft)/1000(ft/in. Hg)] + 0.74 in. Hg\*\*

\*\* 0.74 in. Hg is the nominal correction factor for the reference barometer against which the field barometer was calibrated.

If it is not feasible to perform the audit on any piece of equipment, record "N/A" in the space provided for the data.

Figure 3-17. Mid-test onsite audit data sheet.

**FIELD AUDIT REPORT: DRY GAS METER  
BY CRITICAL ORIFICE**

DATE: 5/19/84 CLIENT: USEPA  
 BAROMETRIC PRESSURE ( $P_{bar}$ ): 29.10 in.Hg METER BOX NO. FB-1  
 ORIFICE NO. 3 PRETEST Y: 0.965  $\Delta H@$  1.72 in.H<sub>2</sub>O  
 ORIFICE K FACTOR:  $5.377 \times 10^{-4}$  AUDITOR: Phillips

Orifice manometer reading $\Delta H$ ,  in. H <sub>2</sub> O	Dry gas meter reading $V_i/V_f$ ,  ft <sup>3</sup>	Temperatures					Duration of run $\phi$ min.
		Ambient		Dry gas meter			
		$T_{ai}/T_{af}$ ,  °F	Average $T_a$ ,  °F	Inlet $T_{ii}/T_{if}$ ,  °F	Outlet $T_{oi}/T_{of}$ ,  °F	Average $T_m$ ,  °F	
2.15	490.025	78	78	79	71	76.25	15.0
	503.330	78		82	73		

Dry gas meter $V_m$ , ft <sup>3</sup>	$V_{mstd}$ , ft <sup>3</sup>	$V_{mact}$ , ft <sup>3</sup>	Audit, Y	Y deviation, %	Audit $\Delta H@$ , in.H <sub>2</sub> O	$\Delta H@$ Deviation, in.H <sub>2</sub> O
13.305	12.810	12.173	.950	-1.5P	1.75	+0.03

$$V_{mstd} = \frac{17.647(V_m)(P_{bar} + \Delta H/13.6)}{(T_m + 460)} = 12.810 \text{ ft}^3$$

$$V_{mact} = \frac{1203(\emptyset)(K)(P_{bar})}{(T_a + 460)^{1/2}} = 12.173 \text{ ft}^3$$

$$\text{Audit Y} = \frac{V_{mact}}{V_{mstd}} = .950 \quad Y \text{ deviation} = \frac{\text{Audit Y} - \text{Pre-test Y}}{\text{Audit Y}} \times 100 = -1.54\%$$

$$\text{Audit } \Delta H@ = (0.0317)(\Delta H)(P_{bar})(T_m + 460) \left[ \frac{\emptyset}{Y(V_m)(P_{bar} + \Delta H/13.6)} \right]^2 = 1.75 \text{ in.H}_2\text{O}$$

Audit Y must be in the range, pre-test Y  $\pm 0.05$  Y.  
 Audit  $\Delta H@$  must be in the range pre-test  $\Delta H@ \pm 0.15$  inches H<sub>2</sub>O.

Figure 3-18. Post-test audit report: dry gas meter by critical orifice (Meter Box FB-1).

**FIELD AUDIT REPORT: DRY GAS METER  
BY CRITICAL ORIFICE**

DATE: 5/19/84

CLIENT: USEPA

BAROMETRIC PRESSURE ( $P_{bar}$ ): 29.10 in.Hg

METER BOX NO. FB-5

ORIFICE NO. 12

PRETEST Y: 0.983  $\Delta H@$  1.84 in.H<sub>2</sub>O

ORIFICE K FACTOR:  $4.795 \times 10^{-4}$

AUDITOR: Phillips

Orifice manometer reading $\Delta H$ ,  in.H <sub>2</sub> O	Dry gas meter reading $V_i/V_f$ ,  ft <sup>3</sup>	Temperatures					Duration of run $\emptyset$ min.
		Ambient		Dry gas meter			
		$T_{ai}/T_{af}$ ,  °F	Average $T_a$ ,  °F	Inlet $T_{ii}/T_{if}$ ,  °F	Outlet $T_{oi}/T_{of}$ ,  °F	Average $T_m$ ,  °F	
1.90	884.730	78	78	86	80	84	15.0
	896.520	78		88	82		

Dry gas meter $V_m$ , ft <sup>3</sup>	$V_{mstd}$ , ft <sup>3</sup>	$V_{mact}$ , ft <sup>3</sup>	Audit, Y	Y devia- tion, %	Audit $\Delta H@$ , in.H <sub>2</sub> O	$\Delta H@$ Devia- tion, in.H <sub>2</sub> O
<u>11.790</u>	<u>11.183</u>	<u>10.855</u>	<u>.971</u>	<u>-1.24</u>	<u>1.91</u>	<u>+ .07</u>

$$V_{mstd} = \frac{17.647(V_m)(P_{bar} + \Delta H/13.6)}{(T_m + 460)} = 11.183 \text{ ft}^3$$

$$V_{mact} = \frac{1203(\emptyset)(K)(P_{bar})}{(T_a + 460)^{1/2}} = 10.855 \text{ ft}^3$$

$$\text{Audit Y} = \frac{V_{mact}}{V_{mstd}} = .971 \quad Y \text{ deviation} = \frac{\text{Audit Y} - \text{Pre-test Y}}{\text{Audit Y}} \times 100 = -1.24\%$$

$$\text{Audit } \Delta H@ = (0.0317)(\Delta H)(P_{bar})(T_m + 460) \left[ \frac{\emptyset}{Y(V_m)(P_{bar} + \Delta H/13.6)} \right]^2 = 1.91 \text{ in.H}_2\text{O}$$

Audit Y must be in the range, pre-test Y  $\pm 0.05$  Y.

Audit  $\Delta H@$  must be in the range pre-test  $\Delta H@ \pm 0.15$  inches H<sub>2</sub>O.

Figure 3-19. Post-test audit report: dry gas meter by  
critical orifice (Meter Box FB-5).

**FIELD AUDIT REPORT: DRY GAS METER  
BY CRITICAL ORIFICE**

DATE: 5/19/84 CLIENT: USEPA  
 BAROMETRIC PRESSURE ( $P_{bar}$ ): 29.10 in.Hg METER BOX NO. FB-8  
 ORIFICE NO. 7 PRETEST Y: 0.990  $\Delta H@$  1.91 in.H<sub>2</sub>O  
 ORIFICE K FACTOR:  $4.964 \times 10^{-4}$  AUDITOR: Phillips

Orifice manometer reading $\Delta H$ ,  in.H <sub>2</sub> O	Dry gas meter reading $V_i/V_f$ ,  ft <sup>3</sup>	Temperatures					Duration of run $\emptyset$ min.
		Ambient		Dry gas meter			
		$T_{ai}/T_{af}$ ,  °F	Average $T_a$ ,  °F	Inlet $T_{ii}/T_{if}$ ,  °F	Outlet $T_{oi}/T_{of}$ ,  °F	Average $T_m$ ,  °F	
2.10	017.800	78	80	84	80	83.5	39 <sup>7.4</sup> <sub>60</sub> 19.12
	049.200	82		87	83		

Dry gas meter $V_m$ , ft <sup>3</sup>	$V_{mstd}$ , ft <sup>3</sup>	$V_{mact}$ , ft <sup>3</sup>	Audit, Y	Y devia- tion, %	Audit $\Delta H@$ , in.H <sub>2</sub> O	$\Delta H@$ Devia- tion, in.H <sub>2</sub> O
31.400	29.826	29.257	.991	-.92	1.98	+.07

$$V_{mstd} = \frac{17.647(V_m)(P_{bar} + \Delta H/13.6)}{(T_m + 460)} = 29.826 \text{ ft}^3$$

$$V_{mact} = \frac{1203(\emptyset)(K)(P_{bar})}{(T_a + 460)^{1/2}} = 29.257 \text{ ft}^3$$

$$\text{Audit } Y = \frac{V_{mact}}{V_{mstd}} = .991 \quad Y \text{ deviation} = \frac{\text{Audit } Y - \text{Pre-test } Y}{\text{Audit } Y} \times 100 = -.92\%$$

$$\text{Audit } \Delta H@ = (0.0317)(\Delta H)(P_{bar})(T_m + 460) \left[ \frac{\emptyset}{Y(V_m)(P_{bar} + \Delta H/13.6)} \right]^2 = 1.98 \text{ in.H}_2\text{O}$$

Audit Y must be in the range, pre-test Y  $\pm 0.05$  Y.  
 Audit  $\Delta H@$  must be in the range pre-test  $\Delta H@ \pm 0.15$  inches H<sub>2</sub>O.

Figure 3-20. Post-test audit report: dry gas meter by critical orifice (Meter Box FB-8).



**FIELD AUDIT REPORT: DRY GAS METER  
BY CRITICAL ORIFICE**

DATE: 5/19/84 CLIENT: USEPA  
 BAROMETRIC PRESSURE ( $P_{bar}$ ): 29.10 in.Hg METER BOX NO. FB-10  
 ORIFICE NO. 6 PRETEST Y: 0.967  $\Delta H\theta$  1.81 in.H<sub>2</sub>O  
 ORIFICE K FACTOR:  $5.241 \times 10^{-4}$  AUDITOR: Phillips

Orifice manometer reading $\Delta H$ ,  1n.H <sub>2</sub> O	Dry gas meter reading $V_i/V_f$ ,  ft <sup>3</sup>	Temperatures					Duration of run $\theta$ min.
		Ambient		Dry gas meter			
		$T_{ai}/T_{af}$ ,  °F	Average $T_a$ ,  °F	Inlet $T_{ii}/T_{if}$ ,  °F	Outlet $T_{oi}/T_{of}$ ,  °F	Average $T_m$ ,  °F	
2.20	722.900	78	78	94	80	87.5	19 <sup>423</sup> 60 192.5
	739.900	78		95	81		

Dry gas meter $V_m$ , ft <sup>3</sup>	$V_{mstd}$ , ft <sup>3</sup>	$V_{mact}$ , ft <sup>3</sup>	Audit, Y	Y devia- tion, %	Audit $\Delta H\theta$ , in.H <sub>2</sub> O	$\Delta H\theta$ Devia- tion, in.H <sub>2</sub> O
17.100	16.128	15.587	.966	-.10	1.85	+.04

$$V_{mstd} = \frac{17.647(V_m)(P_{bar} + \Delta H/13.6)}{(T_m + 460)} = 16.128 \text{ ft}^3$$

$$V_{mact} = \frac{1203(\theta)(K)(P_{bar})}{(T_a + 460)^{1/2}} = 15.587 \text{ ft}^3$$

$$\text{Audit } Y = \frac{V_{mact}}{V_{mstd}} = .966 \quad Y \text{ deviation} = \frac{\text{Audit } Y - \text{Pre-test } Y}{\text{Audit } Y} \times 100 = -.10\%$$

$$\text{Audit } \Delta H\theta = (0.0317)(\Delta H)(P_{bar})(T_m + 460) \left[ \frac{\theta}{Y(V_m)(P_{bar} + \Delta H/13.6)} \right]^2 = 1.85 \text{ in.H}_2\text{O}$$

Audit Y must be in the range, pre-test Y  $\pm 0.05$  Y.  
 Audit  $\Delta H\theta$  must be in the range pre-test  $\Delta H\theta \pm 0.15$  inches H<sub>2</sub>O.

Figure 3-21. Post-test audit report: dry gas meter by  
critical orifice (Meter Box FB-10).

**THERMOCOUPLE DIGITAL INDICATOR  
AUDIT DATA SHEET**

Date 5/19/84 Indicator No. 220 Operator Phillips

Test Point No.	Millivolt signal*	Equivalent temperature, °F*	Digital indicator temperature reading, °F	Difference, %
1		32	33	.20
2		200	202	.30
3		540	539	.01
4		1194	1194	.00

Percent difference must be less than or equal to 0.5%.

Percent difference:

$$\frac{(\text{Equivalent temperature } ^\circ\text{R} - \text{Digital indicator temperature reading } ^\circ\text{R})(100\%)}{(\text{Equivalent temperature } ^\circ\text{R})}$$

Where  $^\circ\text{R} = ^\circ\text{F} + 460^\circ\text{F}$

\* These values are to be obtained from the calibration data sheet for the calibration device.

Figure 3-22. Post-test thermocouple digital indicator audit data sheet (Indicator No. 220).

**THERMOCOUPLE DIGITAL INDICATOR  
AUDIT DATA SHEET**

Date 5-19-84 Indicator No. 221 Operator *[Signature]*

Test Point No.	Millivolt signal*	Equivalent temperature, °F*	Digital indicator temperature reading, °F	Difference, %
1		32	29	.61
2		200	199	.15
3		540	538	.17
4		1194	1194	.00

Percent difference must be less than or equal to 0.5%.

Percent difference:

$$\frac{(\text{Equivalent temperature } ^\circ\text{R} - \text{Digital indicator temperature reading } ^\circ\text{R})(100\%)}{(\text{Equivalent temperature } ^\circ\text{R})}$$

Where  $^\circ\text{R} = ^\circ\text{F} + 460^\circ\text{F}$

\* These values are to be obtained from the calibration data sheet for the calibration device.

Figure 3-23. Post-test thermocouple digital indicator audit data sheet (Indicator No. 221).

**FIELD AUDIT REPORT: DRY GAS METER  
BY CRITICAL ORIFICE**

DATE: 5-11-84

CLIENT: USEPA-QAD

BAROMETRIC PRESSURE ( $P_{bar}$ ): 29.00 in.Hg

METER BOX NO. FB 2

ORIFICE NO: 7

PRETEST Y: 0.989  $\Delta H$  1.73 in.H<sub>2</sub>O

ORIFICE K FACTOR:  $4.964 \times 10^{-4}$

AUDITOR: [Signature]

Orifice manometer reading $\Delta H$ , in. H <sub>2</sub> O	Dry gas meter reading $V_i/V_f$ , ft <sup>3</sup>	Temperatures					Duration of run $\emptyset$ min.
		Ambient		Dry gas meter			
		$T_{ai}/T_{af}$ , °F	Average $T_a$ , °F	Inlet $T_{ii}/T_{if}$ , °F	Outlet $T_{oi}/T_{of}$ , °F	Average $T_m$ , °F	
1.90	624.800	68	68	70	67	68.5	16 <sup>18.2</sup> / <sub>60</sub>
	638.300	68		70	67		

Dry gas meter $V_m$ , ft <sup>3</sup>	$V_{mstd}$ , ft <sup>3</sup>	$V_{mact}$ , ft <sup>3</sup>	Audit, Y	Y deviation, %	Audit $\Delta H$ , in.H <sub>2</sub> O	$\Delta H$ Devia- tion, in.H <sub>2</sub> O
<u>13.500</u>	<u>13.138</u>	<u>12.285</u>	<u>0.935</u>	<u>5.78</u>	<u>1.62</u>	<u>0.1 <math>\emptyset</math> ✓</u>

$$V_{mstd} = \frac{17.647(V_m)(P_{bar} + \Delta H/13.6)}{(T_m + 460)} = 13.138 \text{ ft}^3$$

$$V_{mact} = \frac{1203(\emptyset)(K)(P_{bar})}{(T_a + 460)^{1/2}} = 12.285 \text{ ft}^3$$

*Do not use  
CR 5/14*

$$\text{Audit } Y = \frac{V_{mact}}{V_{mstd}} = \quad Y \text{ deviation} = \frac{\text{Audit } Y - \text{Pre-test } Y}{\text{Audit } Y} \times 100 = 5.78$$

$$\text{Audit } \Delta H = (0.0317)(\Delta H)(P_{bar})(T_m + 460) \left[ \frac{\emptyset}{Y(V_m)(P_{bar} + \Delta H/13.6)} \right]^2 = 1.62 \text{ in.H}_2\text{O}$$

Audit Y must be in the range, pre-test Y  $\pm 0.05$  Y.  
Audit  $\Delta H$  must be in the range pre-test  $\Delta H \pm 0.15$  inches H<sub>2</sub>O.

Figure 3-24. Example of unacceptable dry gas meter audit.

PEI personnel calculated the sampling rates on site. The data were rechecked and validated at the end of the test program by computer programming. Some minor discrepancies between the hand calculations and computer printouts resulted primarily because of round-off error. Overall, the data compared favorably. Figure 3-25 presents an example calculation form PEI using during this test program. Computerized example calculations are presented in Appendix A.

As an additional check of the reliability of the method used to analyze the samples, two blank trains were assembled in the recovery area, capped off, and set aside for about 2 hours. The first blank train was assembled at the beginning of the test series using clean glassware. On the same day as Quad Runs 7, 8, and 9 (EMSL work), the second blank train was assembled with glassware used during previous sampling runs. The blank trains were recovered in the same manner as the test samples. These samples were shipped to the laboratory and analyzed by the same procedures as those used for the actual emission samples. In addition to the blank sampling train, aliquots of the field reagents used in the collection and recovery of the samples were obtained daily and analyzed by the same procedures as those used for the actual samples. Table 3-2 presents the results of the blank sample trains and field blank analyses. The results are considered reasonable and indicate that background arsenic contamination was not a problem in the sample recovery area. The results of the blanks are relatively small.

ISOKINETIC CALCULATION 41.494

SITE Indiana Glass Co.

TEST NO. 10

		RUN 1	RUN 2	RUN 3	<del>4</del> 4
1. Volume of dry gas sampled corrected to standard conditions. Note: $V_m$ must be corrected for leakage if any leakage rates exceed $L_g$ .  $V_{m, std} = 17.65 \times V_m \times \left[ \frac{P_{bar} + \frac{\Delta H}{13.6}}{14.7} \right]$  $13.226$ $45.403$ $57.107$	$V_m, ft^3$	39.977	41.523	44.003	52.027
	$\gamma$	.965	.983	.967	.980
	$P_{bar}, in. Hg$	29.48	29.48	29.48	29.48
	$\Delta H, in. H_2O$	.903	1.16	1.15	2.11
	$\bar{T}_m, ^\circ R$	529	544	534	531
	$V_{m, std}, dscf$	38.024	39.156	41.573	52.79
2. Volume of water vapor at standard conditions, ft.  $V_{w, std} = 0.04707 V_{lc}$	$V_{lc}, g$	73.8	86.4	81.4	93.4
	$V_{w, std}, ft^3$	3.47	4.07	3.83	4.40
3. Moisture content in stack gas.  $B_{ws} = \frac{V_{w, std}}{V_{m, std} + V_{w, std}}$	$B_{ws}$	.064	.094	.084	.077
	$1 - B_{ws}$	.916	.906	.916	.923
4. Dry molecular weight of stack gas, lb/lb-mole.  $M_d = 0.440 (\% CO_2) + 0.320 (\% O_2) + 0.280 (\% N_2 + \% CO)$	$\% CO_2$	4.3			
	<del><math>\% CO_2</math></del>	12.7			
	$\% N_2 + \% CO$	83			
	$M_d, lb/lb-mole$	29.2			
5. Molecular weight of stack gas.  $M_s = M_d (1 - B_{ws}) + 18 B_{ws}$	$M_s, lb/lb-mole$	28.259			28.36
6. Stack velocity at stack conditions, fps.  $V_s = 85.49 C_p (avg. \sqrt{\Delta P}) \sqrt{\frac{T_s}{P_s M_s}}$	$P_{static}, in. H_2O$	-.53			
	$P_s, in. Hg$	29.44			
	$\bar{T}_s, ^\circ R$	1036			1039
	$\sqrt{\Delta P}$	.540			.598
	$C_p$	.84			
	$V_s, fps$	43.3			47.8
	$D_n, in.$	.287			.319
7. Isokinetic variation  $\% I = \frac{V_{m, std} \times T_s \times 17.22}{V_s \times D_n \times 0 \times P_s \times (1 - B_{ws})}$	$\theta, min.$				
	$\% I$	101.3			102.0

Figure 3-25. Example of onsite calibration data sheet.

TABLE 3-2. ARSENIC BLANK DATA

Blank sample train arsenic values <sup>a</sup>				
Train No.	Filter, $\mu\text{g}$	NaOH probe rinse, $\mu\text{g}$	Impinger section, $\mu\text{g}$	Total train blank, $\mu\text{g}$
1	32.8	8.0	22.2	63.0
2	30.8	7.8	11.6	50.2

Field blank arsenic values				
Date samples taken	Corresponding Run No.	Filter total, $\mu\text{g}$	NaOH <sup>b</sup> , mg/liter	H <sub>2</sub> O <sup>c</sup> , mg/liter
5/17/84	10 + 11	26.7	0.0168	0.0085
5/18/84	12 + 13	29.3	0.0137	0.0101
5/19/84	CD1 - CD3	28.8	0.0153	0.0111
Average blank values		28.3	0.0153	0.0099

<sup>a</sup>Sample train was fully assembled in recovery area and then recovered and analyzed as a sample.

<sup>b</sup>Between 235 and 238 ml of NaOH was used to rinse the probe. Between 179 and 456 ml of the NaOH was used to rinse Impingers 1 and 2. Between 128 and 184 ml of the NaOH was used to rinse Impingers 3 and 4. Between 119 and 180 ml of the NaOH was used to rinse the connector. The maximum blank for the NaOH corresponds to 6  $\mu\text{g}$  for the probe rinse, 8  $\mu\text{g}$  for the impinger samples, and 3  $\mu\text{g}$  for the connector samples.

<sup>c</sup>On both days, 300 ml of water was added to arsenic Impingers 1 and 2 and 150 ml to Impingers 3 and 4. The maximum blank for the water corresponds to 3  $\mu\text{g}$  for Impingers 1 and 2 and 2  $\mu\text{g}$  for Impingers 3 and 4.

Laboratory reagent blank analyses were performed during the analysis of the field samples. The results of these analyses are presented in Table 3-3. The average value for five filter blanks was 29.7  $\mu\text{g}$  out of a range of 26.7 to 32.8; a blank correction of 30  $\mu\text{g}$  was used to correct all the reported data. All of the blank values for the rinse and impinger samples were near the analytical detection limit of 2 to 8  $\mu\text{g}$ . Because of the variability and relatively small value of the blank, no average value was determined and no blank corrections applied.

Values below 50  $\mu\text{g}$  were considered insignificant and not reported because 8360  $\mu\text{g}$  (7570 on the filter) was the minimum amount of arsenic determined in any train and the blanks for the liquid sample fractions varied considerably.

Each sample was first analyzed by the flame technique. Samples whose concentrations were below 30 mg/liter were also analyzed using the graphite furnace. Actual sample concentrations were either greater than 100 or less than 10 ppm. The 30-mg/liter limit was based on previous experience with Method 108, which indicated good agreement above this level. As the analyses were completed and the data were reduced by the laboratory, the results were reviewed by the Quality Assurance Officer (QAO). The QAO reviewed instrument calibration, the analysis of the standard reference solution (SRS), agreement between flame and furnace results, and general consistency of the data. He then prepared a list of samples for reanalysis.



TABLE 3-3. ARSENIC LABORATORY REAGENT BLANK DATA

Date (1984)	Filter total, $\mu\text{g}$	Rinse, <sup>a</sup> mg/liter	Impingers, <sup>b</sup> mg/liter	Connector, <sup>c</sup> mg/liter
6/8	2.4	0.0079	0.0079	0.0079

<sup>a</sup>Between 235 and 328 ml of sample were received as the rinse fraction. The maximum laboratory reagent blank corresponds to 3  $\mu\text{g}$  for this fraction.

<sup>b</sup>Between 532 and 817 ml of sample were received as the Impingers 1 and 2 fractions and between 280 and 340 ml as the Impingers 3 and 4 fraction. These correspond to maximum laboratory reagent blanks of 6  $\mu\text{g}$  and 3  $\mu\text{g}$ , respectively.

<sup>c</sup>Between 119 and 180 ml of sample were received as the connector fraction. The maximum laboratory reagent blank corresponds to 1  $\mu\text{g}$  for this fraction.

The analysis was performed in five batches by flame atomic absorption. Eighteen sets of standards (0, 10, 30, 50, 80, 100 ppm) were analyzed with the samples. The linear regression data for all the standards analyzed with a given batch of samples are presented in Table 3-4. The average correlation coefficient is 0.9989, out of a range of 0.9994 to 0.9985. The average detection limit is 2.3 ppm. A value of twice the range of the 0-ppm standard above the Y-intercept was used to calculate the detection limit. A standard reference solution independently prepared from  $As_2O_3$  with a nominal value of 150 ppm was analyzed (1-2 dilution) with each set of standards. (Standards were prepared from a commercially available 1000-ppm standard solution.) The average value obtained in the 18 analyses of this standard reference solution (SRS) was 157.4 ppm, with a standard deviation (SD) of 3.81 ppm [2.4 percent relative standard deviation (RSD)]. Only 1 of the 18 determinations made fell outside the range of the mean  $\pm 2$  SD (one was 166 ppm).

These data indicate that the precision and accuracy of the flame atomic absorption analyses are well within acceptable limits. The percent difference of the average measured value of the SRS and its predicted value is 4.9 percent; the RSD of the measured value is 2.4 percent.

The results of the audit samples supplied by EPA and determined by flame atomic absorption (listed in Table 3-5) are consistent with the data just presented. The relatively large difference at 10 ppm is predictable in that it is only 5 times the average detection limit.

TABLE 3-4. LINEAR REGRESSION DATA (FLAME)

Date (1984)	No. of standard curves	Y-intercept	Slope	Correlation coefficient	Detection limit, ppm
6/4	4	0.0031	0.00489	0.9990	2.1
6/5	2	0.0048	0.00500	0.9994	1.2
6/5	2	0.0056	0.00496	0.9985	1.6
6/11	5	-0.0011	0.00490	0.9990	1.6
6/13	5	0.0041	0.00450	0.9987	4.9

TABLE 3-5. ARSENIC AUDIT RESULTS

EPA No.	Lab No.	Volume, ml	Arsenic concentration EPA values, mg As/liter	Measured, mg/liter	Total As, mg
B-3-I	DC329	500	10	10.2	5.12
B-4-I	DC330	500	10	11.7	5.83
G-1-I	DC331	500	100	111	55.6
G-3-I	DC332	500	100	107	53.3
H-1-I	DC333	500	40	43.9	22.0
H-2-I	DC334	500	40	43.9	22.0
B-3-I <sup>a</sup>	DC329	500	10	11.1	5.54
B-4-I <sup>a</sup>	DC330	500	10	10.7	5.34
WP-475 <sup>a</sup> Conc 6	DM562	1000	0.207-0.393	0.356	0.356

<sup>a</sup>Graphite furnace analysis.

Table 3-6 presents the results of 10 samples checked by the method of standard addition. The slopes of all the standard addition analyses are between 0.9 and 1.1 except for those of DM697, DM688, and DM660, which is probably due to an error in the spiking or the fact that no given point was in the regression analysis because a less-than value is unusable. An analysis of the results of the unspiked samples and the X-intercepts (standard addition values) revealed that only Sample DM697 showed a significant difference. The results for DM697 were expected, based on the slope; the results of standard addition show no consistent bias attributable to the sample matrices.

The samples were analyzed by atomic absorption in which graphite furnace techniques were used. All samples below 30 ppm were analyzed by furnace techniques. Sample concentrations were either greater than 100 ppm or less than 10 ppm. Values obtained from flame and furnace techniques cannot be accurately compared below 10 ppm because this value is too close to the flame detection limit. Twelve sets of standards (0, 0.01, 0.05, 0.10, and 0.15 mg/liter) were analyzed with the samples. All the data sets were reduced by linear regression analysis (see Table 3-7). The average correlation coefficient for the linear regression analysis was 0.9970, out of a range of 0.9980 to 0.9954. The average detection limit for the graphite furnace was 0.0033 ppm. A value of twice the range of the 0-ppm standard above the Y-intercept was used to calculate the detection limit.

TABLE 3-6. ARSENIC STANDARD ADDITION RESULTS

Lab Number	Spike, ppm	Previously determined flame, ppm	Measured, ppm	Linear regression analysis
DM643 Filter	0	26.16	22.45	Slope = 0.992
	20		45.58	Y intercept = 23.36
	30		52.03	Corr. = 0.9955
	40		62.70	X intercept = -23.54
DM670 Filter	0	30.07	29.12	Slope = 0.995
	20		47.80	Y intercept = 28.48
	30		56.92	Corr. = 0.9974
	40		69.60	X intercept = -28.64
DM697 Filter	0	31.45	35.35	Slope = 0.769
	20		48.47	Y intercept = 34.55
	30		57.37	Corr. = 0.9964
	40		66.26	X intercept = -44.90
DM736 Filter	0	28.24	26.90	Slope = 1.030
	20		47.36	Y intercept = 27.24
	30		60.48	Corr. = 0.9957
	40		66.93	X intercept = -26.45
DM637 Bomb	0	<2.6	<4.9	Slope = 0.946
	20		10.88	Y intercept = 0.87
	30		18.67	Corr. = 0.9949
	40		29.79	X intercept = -0.92
DM688 Bomb	0	<3.5	<4.9	Slope = 0.845
	20		11.55	Y intercept = 3.2
	30		20.22	Corr. = 0.9999
	40		28.45	X intercept = -3.76
DM650 Rinse	0	<2.9	<4.9	Slope = 0.968
	20		8.44	Y intercept = 0.98
	30		18.89	Corr. = 0.9989
	40		27.79	X intercept = -1.01

(continued)

TABLE 3-6 (continued)

Lab Number	Spike, ppm	Previously determined flame, ppm	Measured, ppm	Linear regression analysis
DM740 Rinse	0	5.5	<4.9	Slope = 0.990
	20		10.66	Y intercept = 0.28
	30		19.11	Corr. = 0.9965
	40		30.45	X intercept = -0.28
DM660 Impinger	0	<2.1	<4.9	Slope = 0.745
	20		11.55	Y intercept = 3.47
	30		17.11	Corr. = 0.9894
	40		26.45	X intercept = -4.66
DM717 Impinger	0	<1.3	<4.90	Slope = 0.900
	20		7.55	Y intercept = 1.64
	30		16.00	Corr. = 0.9994
	40		25.56	X intercept = -1.82

TABLE 3-7. LINEAR REGRESSION DATA (FURNACE)

Date (1984)	No. of standard curves	Y-intercept	Slope	Correlation coefficient	Detection limit, ppm
6/8	2	-0.0011	4.081	0.9980	0.0039
6/11	4	0.0019	4.316	0.9975	0.0028
6/15	4	-0.0014	3.853	0.9954	0.0031



A standard reference solution independently prepared from  $\text{As}_2\text{O}_3$  with a nominal value of 0.0750 ppm was analyzed with each set of standards. (Standards were prepared from a commercially available 1000-ppm standard solution.) The average value obtained for the 21 analyses of this SRS was 0.0751 ppm with a standard deviation of 0.0027 (3.6 percent relative standard deviation). Historically, the mean value for this SRS is 0.0762, with a standard deviation of 0.0027. The values obtained for the SRS solution during this project are in good agreement with our historical data. These data indicate that the precision and accuracy of the furnace atomic absorption analyses are well within acceptable limits. The difference in the average measured value of the SRS and its predicted value is 0.2 percent; the RSD of the measured value is 3.6 percent.

The results of audit samples analyzed using the graphite furnace were listed in Table 3-5. These values are consistent with the previous value and the accepted values. The results of duplicate analysis are presented in Table 3-8. The absolute value of the percent difference was calculated according to the following equation.

$$\% \text{ Difference} = \frac{X_1 - X_2}{\bar{X}}$$

where  $X_1$  and  $x_2$  are the individual values

$\bar{X}$  is the average of  $X_1$  and  $X_2$

TABLE 3-8. DUPLICATE ANALYSIS DATA

Sample fraction	Arsenic, g	% Difference
Filter	8,310, 8,470	1.4
	8,770, 9,130	3.0
	9,690, 9,590	1.0
	10,900, 11,100	1.8
	10,900, 11,300	3.6
	10,400, 10,300	1.0
	10,800, 10,700	0.9
	10,900, 10,400	4.7
Bomb	99, 93	6.2
Rinse	351, 294	17.7
	498, 467	6.4
	290, 269	7.5
	610, 648	6.0
	768, 657	15.6
Impinger	50, 48	4.1
	4, 5	22.2
Filter <sup>a</sup>	36, 35	2.8
Bomb <sup>a</sup>	39, 32	19.7
	61, 56	8.5
	40, 28	35.3
	66, 51	25.6
Rinse <sup>b</sup>	678, 693	2.2
	623, 629	1.0
Impinger <sup>b</sup>	35, 30	15.4
	32, 29	9.8
	4, 49	170
	227, 191	17.2
	33, 30	9.5
	5, 45	160
	43, 39	9.8
	153, 55	94

<sup>a</sup>Same aliquot analyzed on different days.

<sup>b</sup>Sample aliquot prepared and analyzed on different days.

Filter samples were analyzed using flame atomic absorption, and all other sample fractions were analyzed using the graphite furnace technique.

The first 16 values reported are based on duplicate analysis of the same sample aliquot on the same day using the same calibration curves. The agreement on the front filters is very good. These filters contained better than 90 percent of the total arsenic collected. The average percent difference for the primary filter is 2.4 percent. The agreement for the other sample fractions is acceptable and will not have a significant influence on the overall method precision because they represent less than 10 percent of the total arsenic collected.

The next five values reported are based on repeat analysis of the same sample aliquot on different days using different calibration curves. The agreement is good considering the relatively small amount of arsenic contained in these fractions.

The last 10 values reported are based on repeat analysis of different sample aliquots prepared and analyzed on different days using different calibration curves. The agreement for the two rinse samples (the only two containing a significant amount of arsenic) is very good.

## SECTION 4

### SAMPLING LOCATION AND TEST METHODS

This section describes the sampling sites and test methods used to characterize arsenic emissions from each source evaluated.

A four-train (quad) sampling system was used to collect samples at the exit stack of the glass melting furnace. This system allows four trains to sample simultaneously at essentially a single point in the stack (see Figures 4-1 and 4-2).

Because this sampling approach allows four trains to sample simultaneously at essentially a single point, it reduces the effect of variations in the velocity and particulate profiles on the sampling results. It also permits a statistically significant number of samples to be taken in a short amount of time. Further, since all four trains are identical for every run, the within-train precision can be determined at the same time as the relationship of the different trains is being compared. This methodology for determining method precision was developed and validated in a previous EPA study.\* A total of four quad-train runs representing 16 individual samples were collected. During

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\* Mitchell, W. J., and M. R. Midgett. A Means to Evaluate the Performance of Stationary Source Test Methods. ES and T, 10:85-88, 1976.

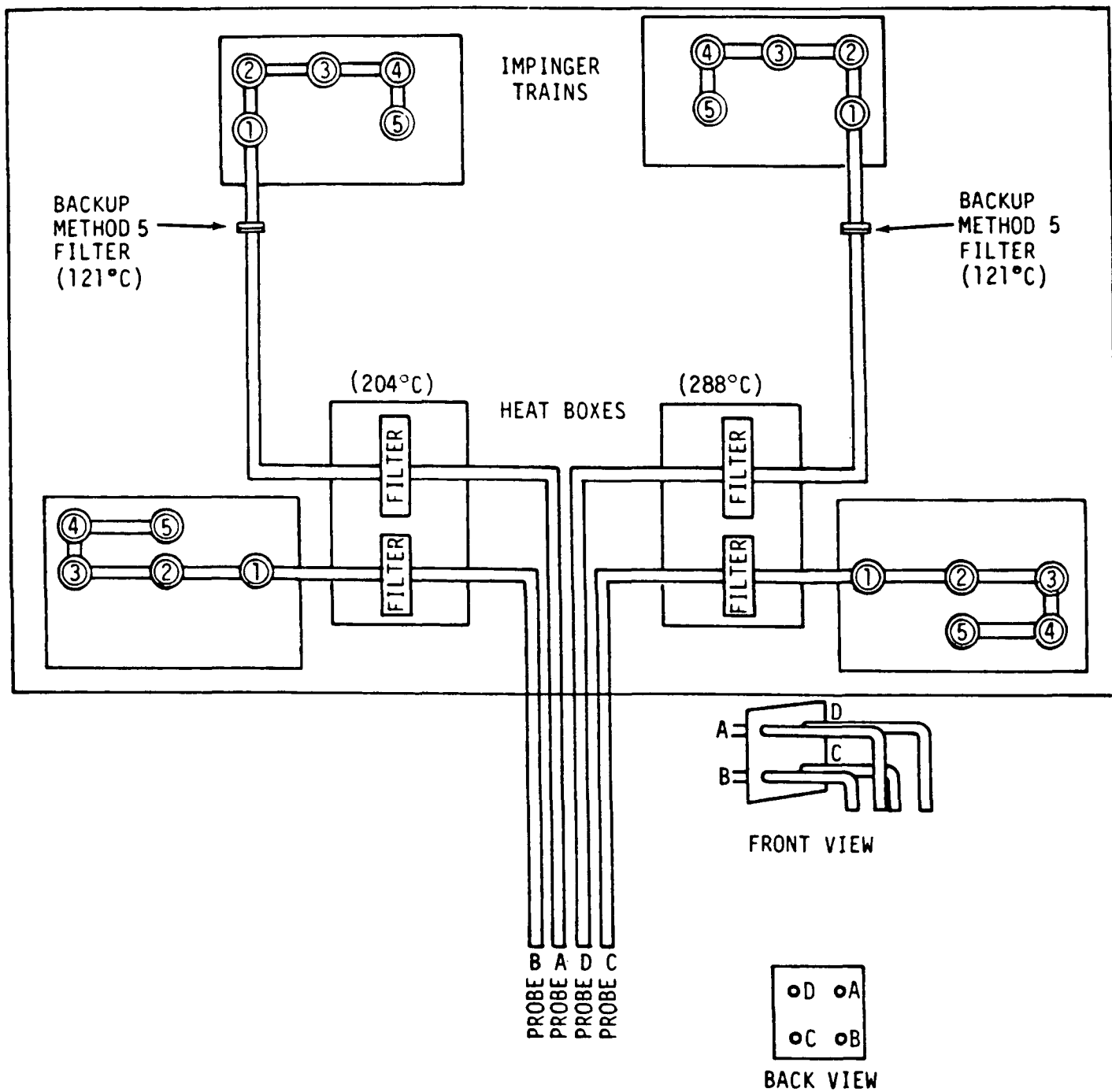


Figure 4-1. Quad train system for elevated temperature tests.

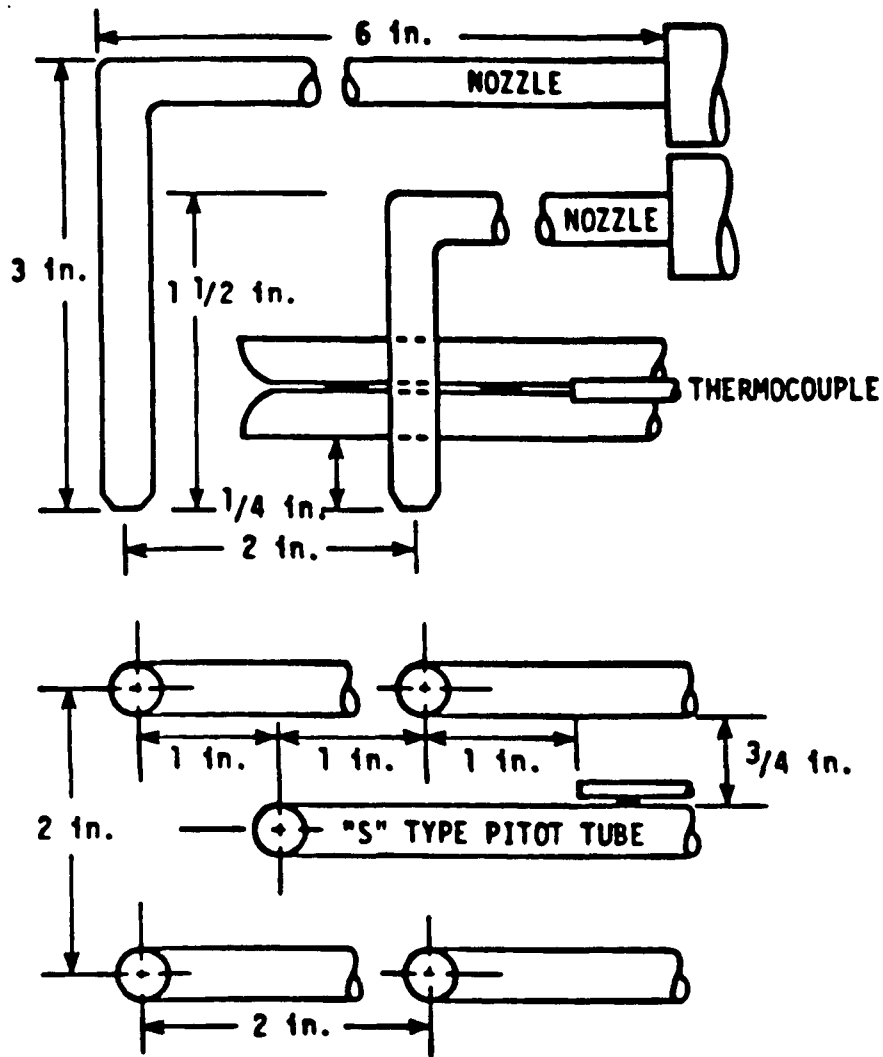


Figure 4-2. Four-train sampling system showing nozzle, pitot tube, and thermocouple position.

these runs, a single Method 108 train was run with the nozzle positioned as close to the quad nozzle arrangement as possible without causing interference.

All samples were collected at the furnace exit stack as depicted in Figures 4-3 and 4-4. Ambient ejector air is controlled automatically to maintain furnace pressure and is introduced angularly as depicted in Figure 4-3 at a volume ratio of about 1:1 to the furnace gases. According to plant personnel, the furnace gas temperature is about 760°C (1400°F), and exit gas temperatures ranged between 260° and 316°C (500° and 600°F), which indicated that the gases were relatively well mixed at the sample cross section. Single-point, isokinetic sampling techniques were used in each quad run and reference train tests. Prior to sampling, a complete velocity and temperature profile was established using procedures described in EPA Methods 1 and 2.\* The velocity and temperature data were used to select sample nozzle sizes so as to maintain isokinetic sample rates and ensure adequate sample volume [0.85 dscm (30 dscf)] in each train. The quad nozzle assembly was positioned approximately 52 cm (20.5 in.) from the inside wall of the stack in each run. Sampling rates generally ranged between 0.014 dsm<sup>3</sup>/m (0.50 dscf/m) and 0.017 dsm<sup>3</sup> (0.60 dscf/m), and sampling times were typically 60 and 70 minutes.

In the Method 108 traverse tests, 24 sampling points were used to traverse the cross-sectional area of the stack. Each

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\* 40 CFR 60, Appendix A, Reference Methods 1 and 2, July 1983.

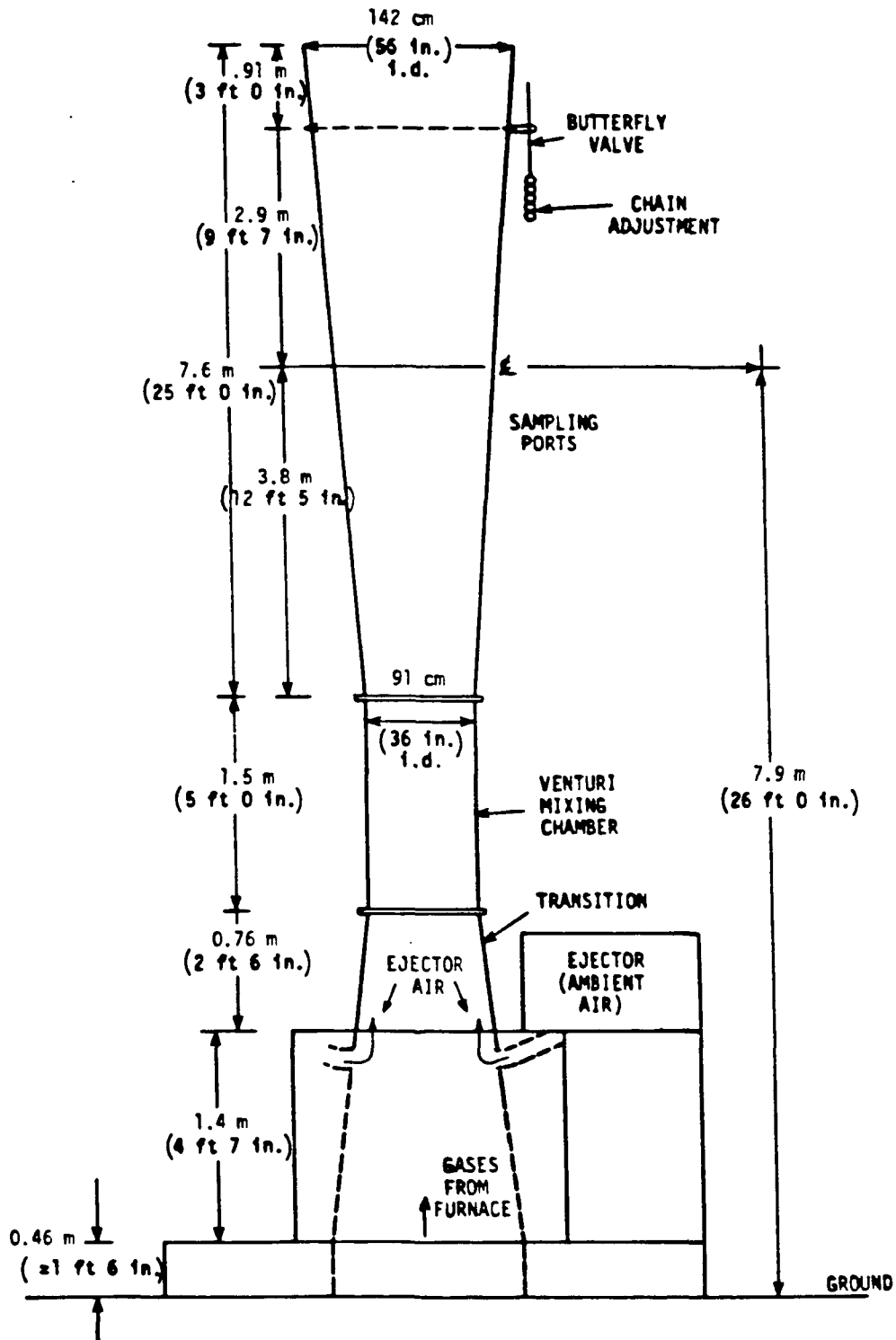


Figure 4-3. Furnace exit stack elevation (no scale).



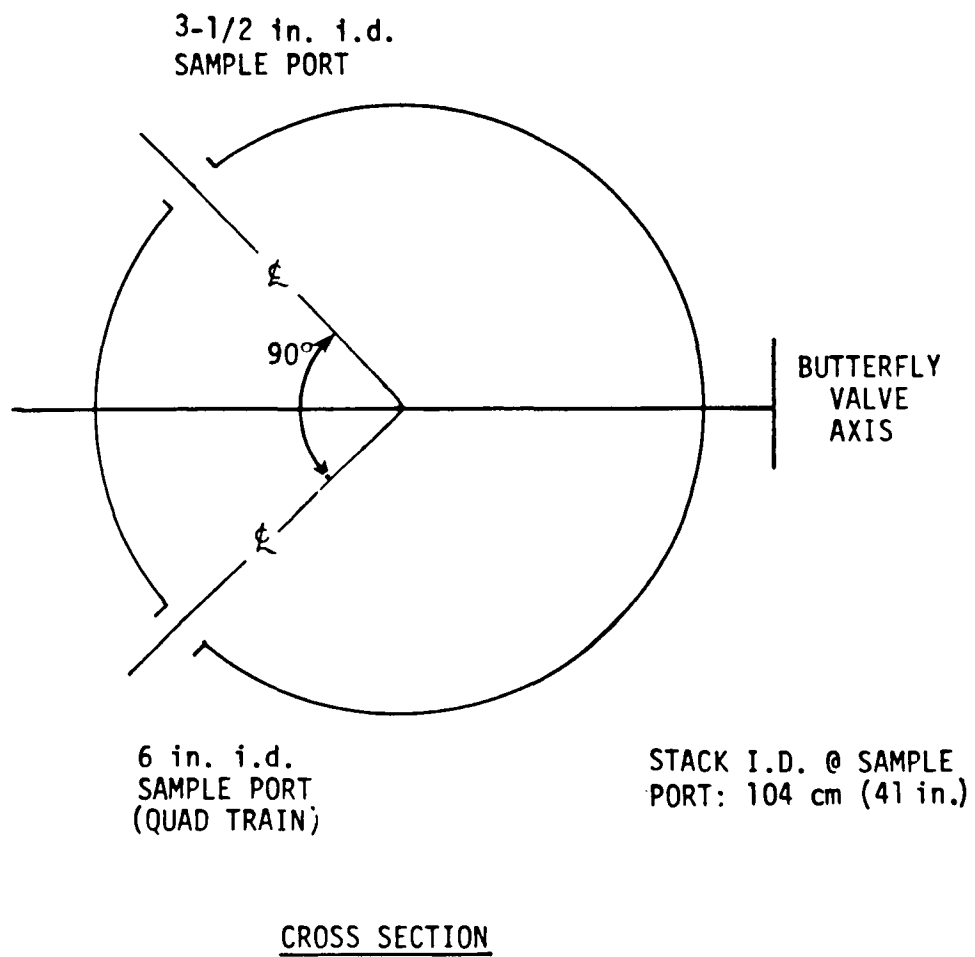


Figure 4-4. Furnace exit stack sampling port location  
(no scale).

point was sampled for 2.5 minutes, yielding a total test time of 60 minutes.

#### 4.1 SAMPLING AND ANALYTICAL PROCEDURES

The sampling and analytical procedures used in this test program followed those described in EPA Reference Methods 1 through 4\* and proposed Method 108 as detailed in the site test plan prepared by PEI and reviewed by EMB. The procedures, which are described briefly here, are detailed in Appendices D and F.

##### 4.1.1 Velocity and Gas Temperature

A Type-S pitot tube and an inclined draft gauge manometer were used to measure gas velocity pressures at the test sites. Temperature was measured with a thermocouple and digital readout. During each sample run, velocity and temperature measurements were taken at a single sampling point in the duct. Prior to each test series, separate velocity measurements were taken by traversing the entire sample cross-sectional area to determine an average value. Measurements were taken in accordance with procedures outlined in Reference Method 2 of the Federal Register.\*

##### 4.1.2 Molecular Weight

Flue gas composition was determined in accordance with the basic procedures described in Reference Method 3.\* Grab samples were collected before any sampling began to establish baseline contents of oxygen, carbon dioxide, and carbon monoxide. Bag

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\* 40 CFR 60, Appendix A, Reference Methods 1 through 4, July 1983.

samples were collected at least twice daily during sampling at each source and analyzed with an Orsat gas analyzer. An integrated bag sample was also collected during each Method 108 traverse test and analyzed using an Orsat gas analyzer.

Method 108\* was used to measure arsenic concentration except that the impingers containing hydrogen peroxide ( $H_2O_2$ ) for  $SO_2$  determination were eliminated due to low (less than 30 ppm) concentrations of  $SO_2$ . All tests were conducted isokinetically by regulating the sample flow rate relative to the gas velocity in the stack as measured by the pitot tube and thermocouple attached to the quad probe arrangement (see Figure 4-2). Each individual sampling train consisted of a heated glass-lined probe, a heated 7.6-cm (3-in.) diameter glass fiber filter (Whatman Reeve Angel 934AH), and a series of four Greenburg-Smith impingers followed by a vacuum line, vacuum gauge, leak-free vacuum pump, dry gas meter, thermometers, and a calibrated orifice. In each train, probe and filter temperatures were monitored using digital indicators and thermocouple leads located in each probe and immediately behind the Method 108 filter frit. In Quad Runs 10, 12, and 13, a 53-cm (21-in.) glass connector was used to attach the front filter to a backup filter maintained at approximately 121°C. The impingers followed the backup filter in these runs.

The amount of water collected in the impinger section of the sampling train was measured gravimetrically at the end of each

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\*Method 108 is proposed. 40 CFR 61, Appendix B, Method 108, July 1983.

sample run to determine the moisture content of the flue gas. The contents of the first two impingers, each of which had been charged initially with 150 ml of distilled water, were transferred to a polyethylene container. These impingers and all connecting glassware (including the back half of the filter holder) as well as a third (empty) impinger were rinsed with 0.1 N NaOH; the rinse was then added to the container. The contents of the first two impingers and 0.1 N NaOH rinse were analyzed for arsenic by atomic absorption. In the elevated temperature runs, the third and fourth impingers were recovered and analyzed similar to Impingers 1 and 2.

## SECTION 5

### PROCESS OPERATION

Tests were performed on the uncontrolled emissions from a regenerative natural-gas-fired glass melting furnace. The furnace evaluated has a pull-rate capacity of 90 to 100 tons/day and produces primarily crystal glass utilizing arsenic as a conditioning and refining agent. Furnace pressure is maintained by use of an induced-draft ejector system as described in Section 4. Data collected during this study indicate that the furnace gases and the ejector air were adequately mixed at the sampling location.

Personnel from Radian Corporation (an EPA contractor) monitored the furnace operation during each test. Appendix F of this report contains a detailed process description and a summary of furnace operating data.